SURVEYOR
LUNAR ROVING VEHICLE,
PHASE I

BSR-903

FINAL TECHNICAL REPORT

SUBMITTED TO

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

JPL CONTRACT
950656

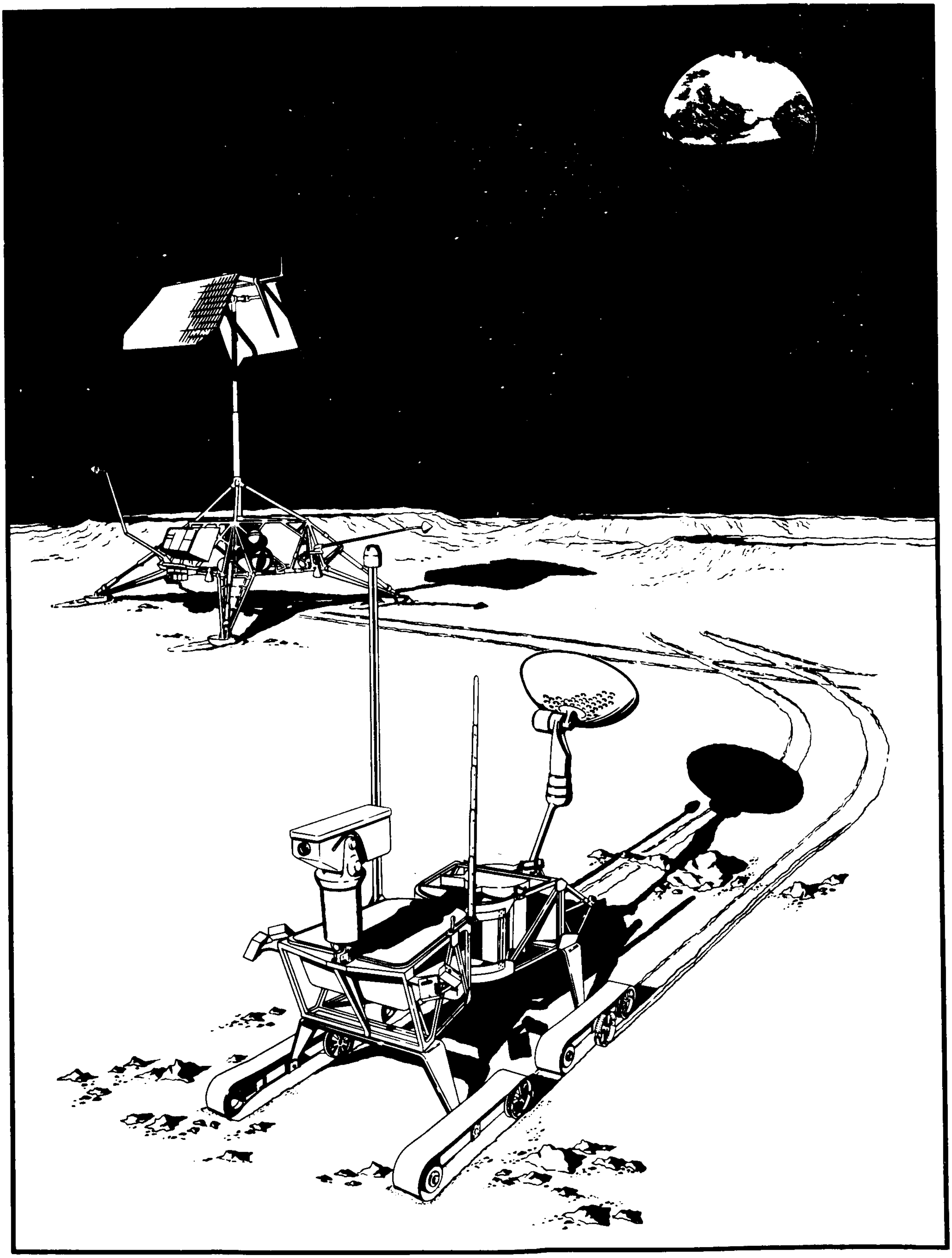
VOLUME III
PRELIMINARY DESIGN AND SYSTEM DESCRIPTION

BOOK 1

SYSTEM DESCRIPTION AND PERFORMANCE CHARACTERISTICS

APRIL 1964

Bendix SYSTEMS DIVISION



FOREWORD

As part of the continuing program of unmanned exploration of space, and to increase the effectiveness of the manned space program for exploring the moon, the Jet Propulsion Laboratory of the California Institute of Technology issued six-month study contracts to investigate the feasibility of a small, unmanned, lightweight, remotely controlled roving vehicle to be incorporated in the surveyor spacecraft to extend its data-gathering capabilities on the lunar surface. Specifically, the study program was to determine the feasibility of a 100-lb Surveyor Lunar Roving Vehicle (SLRV) system in gathering sufficient scientific information by surveying the lunar surface near the Surveyor spacecraft landing point to certify the area, in terms of specific hazards, as a potential Apollo LEM landing site.

This Final Technical Report, submitted in five volumes, presents the results and conclusions of the study program conducted by The Bendix Corporation under JPL Contract No. 950656. The volumes are organized to correspond to the specific objectives of the program: to conduct an analysis, to generate a preliminary design, and to fabricate and demonstrate an engineering test model in support of the over-all program objectives.

The results of Bendix's study show that the SLRV concept is not only feasible, but can make substantial contributions to the unmanned exploration of the moon in support of the manned Apollo program. The SLRV characteristics, the problems, and the initial trade-offs have been determined in sufficient detail to permit the definition of specific objectives and criteria for a follow-on development program. Program conclusions and recommendations are included in Volume V.

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SECTION 1

INTRODUCTION

This volume of the Final Technical Report presents the results of the Phase I SLRV study program in accordance with two sections of Article I of the Statement of Work of JPL Contract No. 950656, Modification No. 1. Section 2 herein is in response to Section (a) (1) (ii) of the Contract, which states:

> "Prepare a preliminary design and system description for the proposed configuration, which shall include, but not necessarily be limited to, the following:
>
> (A) Configuration, including all subsystems and instrumentation
>
> (B) Weight breakdown, including center of gravity and moments of inertia
>
> (C) Power profile
>
> (D) Operational sequence
>
> (E) Ground operational equipment"

Section 3 herein is in response to Section (a) (1) (v) of the Contract, which states:

> "Analyze the performance characteristics and limitations of the proposed design."

SECTION 2

SYSTEM DESCRIPTION

The SLRV system is composed of the Lunar Roving Vehicle (SLRV) the Surveyor Spacecraft modifications, the Ground Operating Equipment (GOE), and the Ground Support Equipment (GSE). These elements are operated in conjunction with the Surveyor Spacecraft, the DSIF, and the Centaur launch vehicle.

The vehicle is a four-tracked articulated design and is divided into two main sections. The aft section contains the radioisotope thermoelectric generator (RTG), the directional antenna, and the odometer. The forward section contains the electronic equipment, the penetrometer, the omnidirectional antenna, the RF ranging antenna, the TV system, and four digital solar aspect sensors.

In the stowed configuration, the vehicle rests on a set of mounting brackets (hinges) in a near vertical position, constrained against a depressed spring-loaded ejector. The mounting brackets are designed such that one set is fixed to the Surveyor spacecraft structure and the other set is fixed to the vehicle structure. These brackets serve as primary load carrying members during the launch and landing operations and as hinges during the deployment procedure.

The Lunar Roving Vehicle operates independently of the Surveyor spacecraft, communicating directly with the ground control station.

The steering capability is provided by differentially controlling the speed of the four independently-powered tracks, and by an articulated structure which pivots near the center of gravity. The power is supplied by a RTG. The vehicle is designed to survive the environments of lunar night.

Provision is made for continuous transmission of telemetry data back to the earth. The experimental information is obtained with a TV system, a penetrometer, an inclinometer, and an odometer. Navigation is accomplished by a dead-reckoning system. RF ranging supplies range information with respect to the Surveyor. Vehicle travel consists of short steps in territory examined by TV during vehicle stops. Steering is controlled from the ground station, using an operator-directed, computer-implemented procedure.

The ground operating equipment at the Deep Space Instrumentation Facility DSIF) and Space Flight Operations Facility (SFOF) provides operational control of the vehicle in locating and surveying potential landing sites, and analysis and display of the data. The function requires several operators and equipment subsystems.

2.1 SUMMARY OF MISSION AND SYSTEM REQUIREMENTS

The design presented in this volume satisfies a set of system requirements which in turn satisfy a set of mission requirements. Both these sets of requirements are summarized here so that the relation of this volume to the over-all report can be clearly established.

2.1.1 Summary of Mission Requirements

2.1.1.1 Landing Site Diameter and Acceptability

Measurement data shall permit the identification and location of 19 40-meter diameter certified landing points within a site having a diameter of 3200 meters and including the Surveyor touchdown point.

2.1.1.2 Certified Landing Point Spacing

Certified LEM landing points shall be a maximum of 528 meters apart and nominally located at the apexes of contiguous equilateral triangles. The center of the complex of landing points shall define the center of the 3200-meter site.

2.1.1.3 Landing Point Identifications

Three natural or artificial landmarks shall be identified within the site, spaced no less than 1500 meters apart and located relative to each other with an accuracy of 20 meters. Each of the certified LEM landing points shall be located relative to at least one of these landmarks with an accuracy of 20 meters. Orientation of the landing point pattern in lunar coordinates shall be provided.

The landmarks must be identifiable by the LEM crew during descent to the lunar surface from a slant range of up to 4400 meters and a minimum depression angle of 29°. Artificial landmarks must retain their identifying characteristics for a period of not less than one year.

2.1.1.4 Soil Bearing Strength Measurements

Measurements of the soil characteristics shall be of sufficient accuracy to verify that the landing points have an equivalent linear dynamic soil bearing strength gradient of at least 12 psi per foot for depths up to 50 cm at impact velocities of up to 3 meters per second.

2.1.1.5 Slope Measurements

Measurements data shall be sufficiently accurate to verify that the landing points contain effective slopes no greater than 12° over any area greater than 10 meters in diameter. An effective slope is defined as the general surface slope over an area too large for the LEM to straddle, plus the combined effects of superimposed heights, depressions, and surface sinkage.

2.1.1.6 Protuberances

Measurements shall be of sufficient accuracy to verify that the landing points contain no effective protuberances greater than 50 cm. An effective protuberance is defined as the surface and subsurface relief within a horizontal distance of approximately 10 meters which might cause the bottoming or tilting of the LEM. Effective protuberances may result from single objects, such as blocks, or complex combinations of heights, depressions, and surface sinkage.

2.1.1.7 Confidence in Acceptability of Certified Landing Points

The data derived from all measurements within each certified landing point must provide a 0.99 confidence that 100% of the landing point area satisfies the acceptability criteria stated above.

2.1.1.8 Mission Probability of Success

The probability of achieving the primary mission objective shall be 0.50. This probability includes the launch vehicle and Surveyor Spacecraft success probabilities and is applicable to a total of eight SLRV missions.

2.1.2 Summary of System Requirements

2.1.2.1 Landing Point Pattern

The desired pattern of certified points in the site is shown in Figure 3-1 of Volume II. Terrain conditions may not allow the certification of points precisely in the indicated pattern, but the pattern can be adjusted where necessary with closer spacing between points.

2.1.2.2 Landing Point Spacing and Location Accuracy

Although the pattern of points may be altered to compensate for terrain condidtions, the maximum allowable distance between any two adjacent points is 528 meters from center to center.

All landing points shall be located with an accuracy of 20 meters (3σ) with respect to one of the LEM navigational aid marks (specified below).

2.1.2.3 Landing Point Diameter

Consistent with the above point location accurancy, the landing points shall have a minimum surveyed and certified acceptable area contained within a diameter of 40 meters.

2.1.2.4 Landing Point Identification

The SLRV must be capable of either locating and identifying natural marks or emplacing three artificial marks to serve as navigational aids to the LEM crew. The marks must have the visual qualities specified in Appendix A of Volume II.

Minimum spacing between any two marks shall be 1500 meters. Each mark shall be located with respect to the other two with an accuracy of 20 meters.

2.1.2.5 Landing Point Certification Data

The landing point certification data requirements summarized below are those derived to satisfy the soil bearing strength, effective protuberance, and effective slope measurements specified in Section 2.1.1.

2.1.2.6 Effective Protuberance Data

All surface discontinuities of 20 cm or more change in elevation within the landing point shall be identified with an accuracy of 5 cm minimum.

2.1.2.7 Effective Slope Data

The system shall be capable of providing elevation, protuberance, and bearing strength data so there is a 99% confidence that there are no effective slopes of 12° or greater in a certified landing point.

2.1.2.8 Soil Bearing Strength Data

Soil bearing strength is defined as the force per unit area that the soil will support at a given level of sinkage. The test collected data should be capable of extrapolation to areas larger than 0.30 meter in diameter.

Measurements for bearing strength shall be taken at a minimum of 45 locations distributed over the landing point. The data measurement range shall be sufficient to be correlated to bearing strength of 0.5 to 12 psi with a tolerance of ±20% within this range.

The depth of measurements shall be at least 50 cm unless a force of 12 $lb/in.^2$ is encountered.

2.1.2.9 Mobility

The SLRV shall be capable of traversing the surface models specified in EPD-98, Revision 1, commensurate with a 0.5 probability of successfully certifying 19 acceptable landing points and identifying or emplacing three marks.

2.1.2.10 Data Transmission

Data transmission shall be compatible with the DSIF capabilities as specified in JPL Technical Memorandum No. 33-83.

2.1.2.11 Reliability

The SLRV system reliability shall be commensurate with 0.5 probability of successfully certifying 19 acceptable landing points and identifying or emplacing three marks.

2.1.2.12 Physical and Environmental Contraints

The SLRV shall be compatible with the physical and environmental constraints specified in Section 2 of Volume II.

2.2 SYSTEM INTERGRATION

The SLRV system has been designed to be compatible with the spacecraft and environmental constraints delineated in the following documents:

1. Engineering Planning Document No. 98, Rev. 1: "Requirements for a Roving Vehicle for the Surveyor Spacecraft", Jet Propulsion Laboratory Pasadena, California, 18 November 1963.

2. Technical Memorandum No. 33-83: "System Capabilities and Development Schedule of the Deep Space Instrumentation Facility", Jet Propulsion Laboratory, Pasadena, California, 2 March 1962.

3. HAC Specification No. 235903, Rev. C: "Surveyor Basic Bus (2100 lb) Payload Interface Requirements", Hughes Aircraft Company, El Segundo, California, 21 June 1963.

The exploded view of the vehicle is shown in Figure 2. 2-1. The system block diagram of the SLRV is shown in Figure 2. 2-2. The signal flow within the vehicle is shown in Figures 2. 2-3 and 2. 2-4.

The integrated system consists of defined items which can be represented by the Hardware Trees shown in Figures 2. 2-5 through 2. 2-8. When the functional organization of the equipment is considered the system can be represented by the Functional Specification Tree shown in Figure 2. 2-9.

2.2.1 SLRV Configuration

The SLRV configuration is shown in Figure 2. 2-1 and weighs 100 lb includi Surveyor-mounted equipment. This vehicle has an aluminum alloy truss-type structure. The truss network provides the interconnecting structure for the articulated joint. the RTG power supply, the electronic compartment structure, TV camera, antenna, and the attachment interface to the Surveyor Spacecraft.

The TV camera is mounted on the top of the vehicle structure on a spring-loaded support mast. During flight this assembly is folded and latched near the TV camera to a stowage fitting on the SLRV with an explosive latch pin.

The directional antenna is attached to the structure at the rear of the vehic on a support mast. During flight this antenna assembly is folded and secured with latch pins. A stored-energy power spring raises the antenna after the vehicle has deployed from the Surveyor.

In order to facilitate deployment, the SLRV is hinged to the Surveyor structure and compressed against the deployment springs. The spring latching mechanism supports the vehicle to minimize the launch vibration loads. A support, also provided for holding the SLRV struts and tracks during transit, will be removed prior to SLRV deployment. Deployment commands will be received by the SLRV through an umbilical which is located near the deployment springs.

The mobility subsystem of the SLRV includes four traction drives. Each track is individually powered by a traction drive motor. Differential speed control of these traction motors is used for steering. The steering is accommodated by an articulated body structure using a floating pivot.

The electronic compartment contains all of the functional electronics units for operating the SLRV except for the TV camera. These electronic units are packaged on the under side of the thermal plate which forms the top of the electronics compartment. This plate is one of the essential elements in thermal control. Also mounted in the electronic compartment near the center of the vehicle is the penetrometer for making the soil measurements.

Thermal control of the electronics compartment is achieved by the use of special insulator thermal radiation shields, resistor heaters, and thermal coatings.

Power for the SLRV is supplied by the RTG which is mounted on the back half of the vehicle structure.

2.2.1.1 SLRV-Surveyor Compatibility

The vehicle has been designed so that thermal electrical and mechanical interferences with Surveyor have been minimized. The vehicle lies within the outline specified in the payload envelope except for an apparent interference in area A shown in Figure 2.2-10. In this area, the clearance appears to have been violated by approximately 2 in. at one point. Because of the lack of detail of the Surveyor structural member positions, it is not altogether certain that there is interference. The interference is between the vehicle directional antenna and ejection support mechanism and the Surveyor cross structure members.

2.2.2 Ground Support Equipment (GSE)

The integrated SLRV system requires a selection of appropriate GSE which will function effectively with the vehicle and with the GOE. This GSE provides for functional checkout, servicing, handling, and transportation activities involved during preparation of the SLRV for launch. In addition, functional and mechanical support is provided for the installation and operation of the GOE.

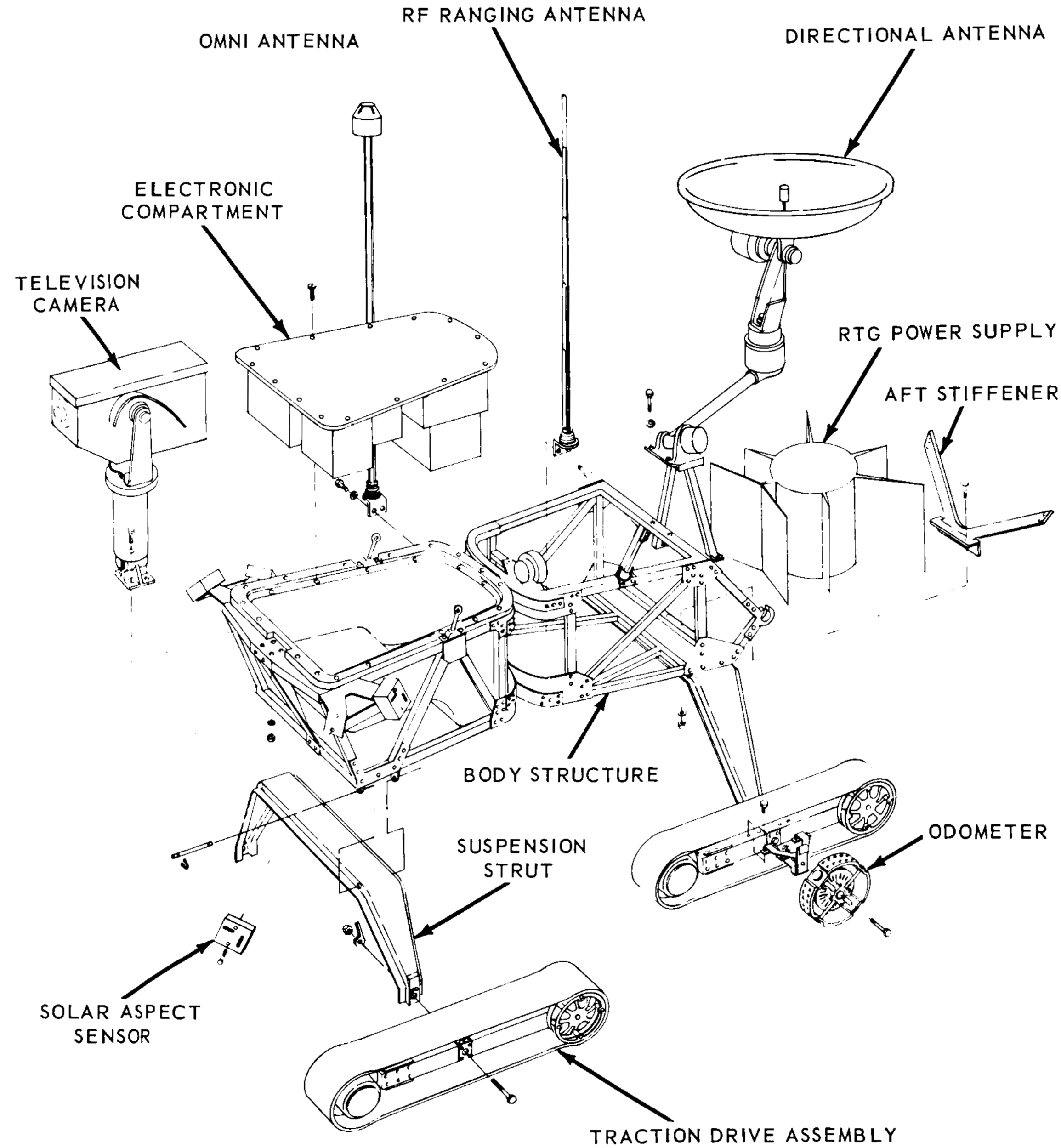
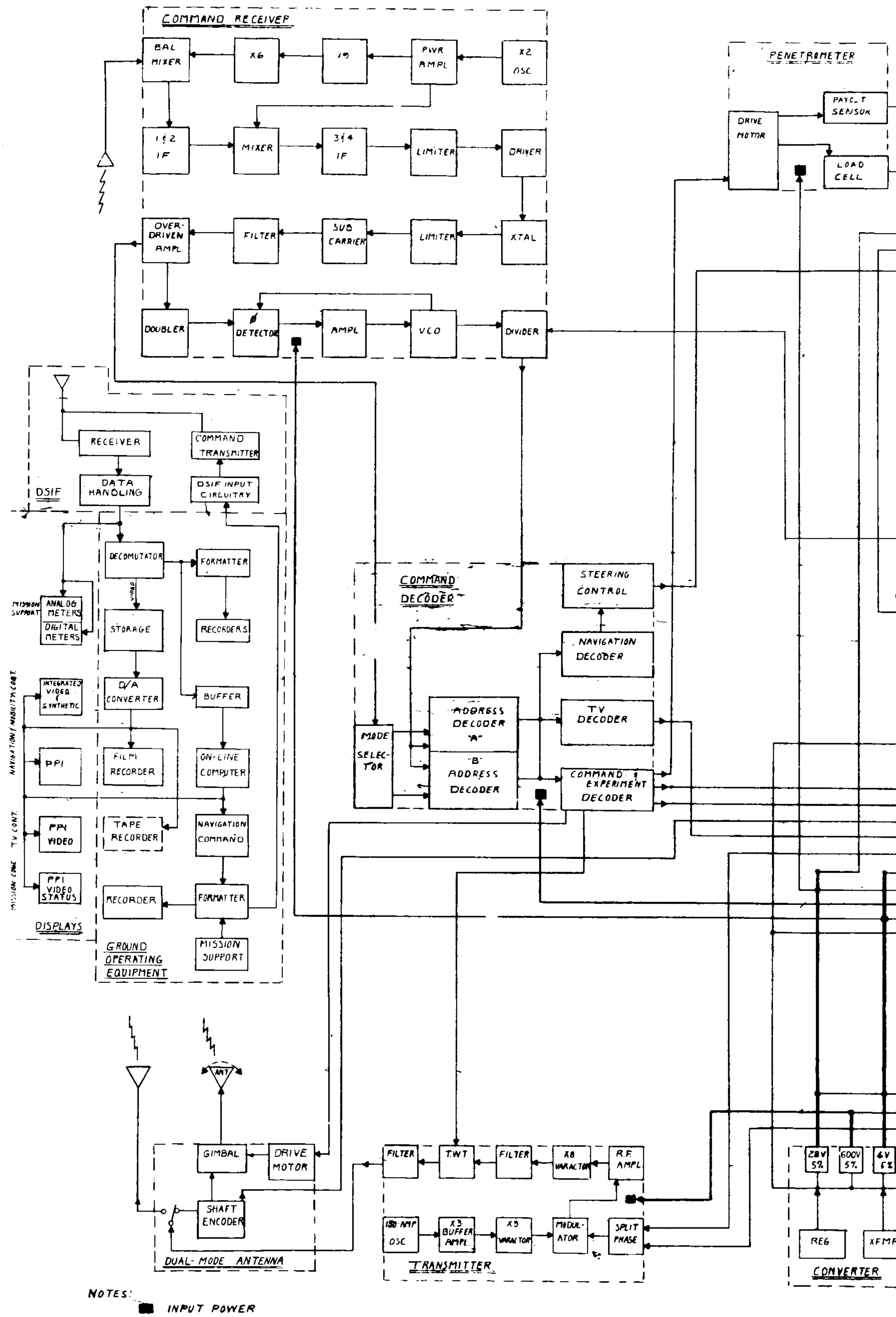


Figure 2.2-1 SLRV Configuration Concept


COMMAND RECEIVER
BAL MIXER
X6
÷9
PWR AMPL
X2 OSC
1 & 2 IF
MIXER
3 & 4 IF
LIMITER
DRIVER
OVER-DRIVEN AMPL
FILTER
SUB CARRIER
LIMITER
XTAL
DOUBLER
ø DETECTOR
AMPL
VCO
DIVIDER
PENETROMETER
DRIVE MOTOR
PAYC. T SENSOR
LOAD CELL
RECEIVER
COMMAND TRANSMITTER
DATA HANDLING
DSIF INPUT CIRCUITRY
DSIF
DECOMUTATOR
FORMATTER
VIDEO
STORAGE
RECORDERS
D/A CONVERTER
BUFFER
FILM RECORDER
ON-LINE COMPUTER
TAPE RECORDER
NAVIGATION COMMAND
RECORDER
FORMATTER
MISSION SUPPORT
GROUND OPERATING EQUIPMENT
MISSION SUPPORT
ANALOG METERS
DIGITAL METERS
INTEGRATED VIDEO & SYNTHETIC
PPI
PPI VIDEO
PPI VIDEO STATUS
NAVIGATION / MOBILITY CONT.
TV CONT.
MISSION CONT.
DISPLAYS
COMMAND DECODER
STEERING CONTROL
NAVIGATION DECODER
ADDRESS DECODER "A"
"B" ADDRESS DECODER
TV DECODER
MODE SELECTOR
COMMAND & EXPERIMENT DECODER
ANT
GIMBAL
DRIVE MOTOR
SHAFT ENCODER
DUAL-MODE ANTENNA
FILTER
TWT
FILTER
X8 VARACTOR
R.F. AMPL
150 MHz OSC
X3 BUFFER AMPL
X9 VARACTOR
MODUL-ATOR
SPLIT PHASE
TRANSMITTER
28V 5%
600V 5%
6V 5%
REG
XFMR
CONVERTER
NOTES:
INPUT POWER

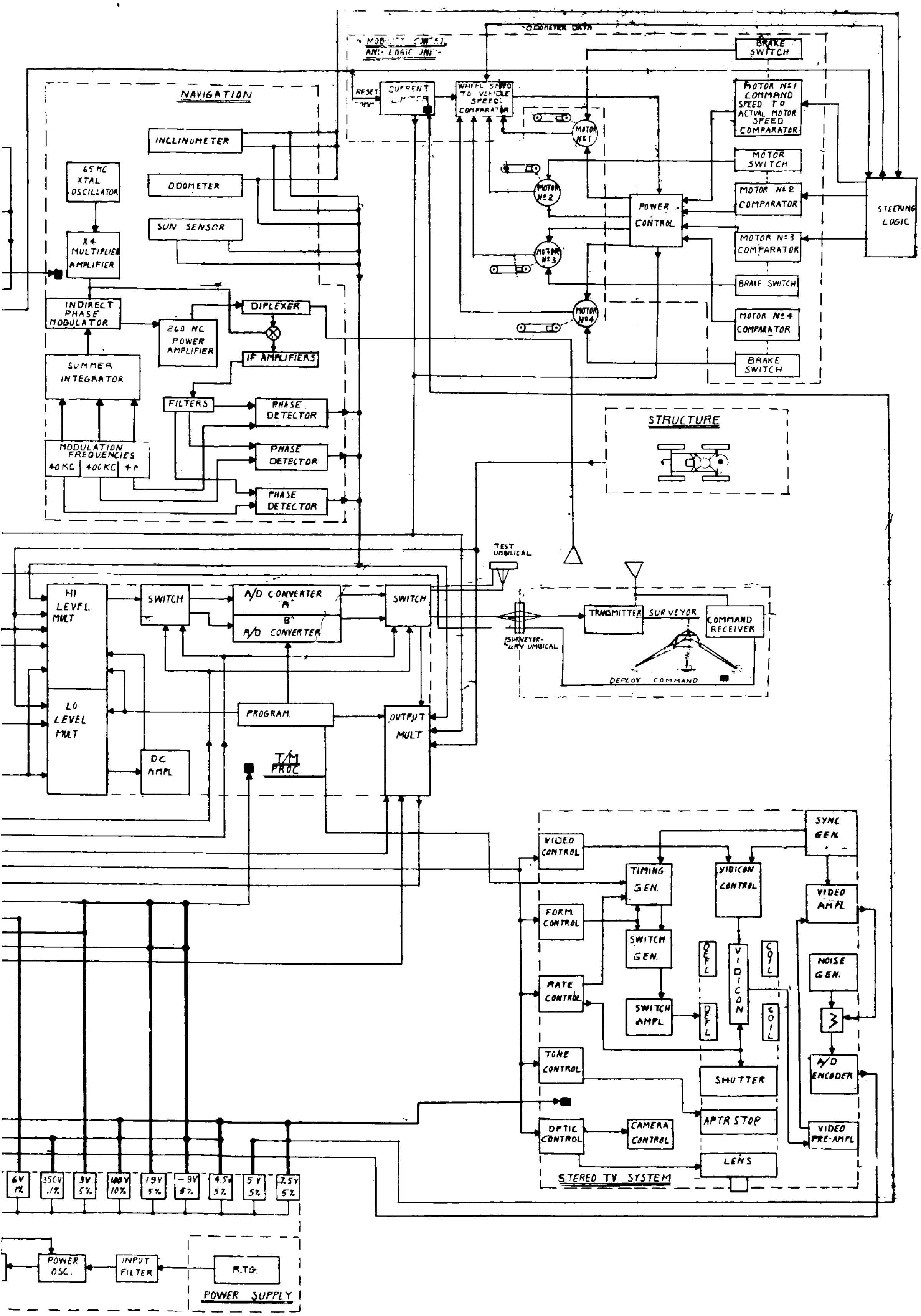
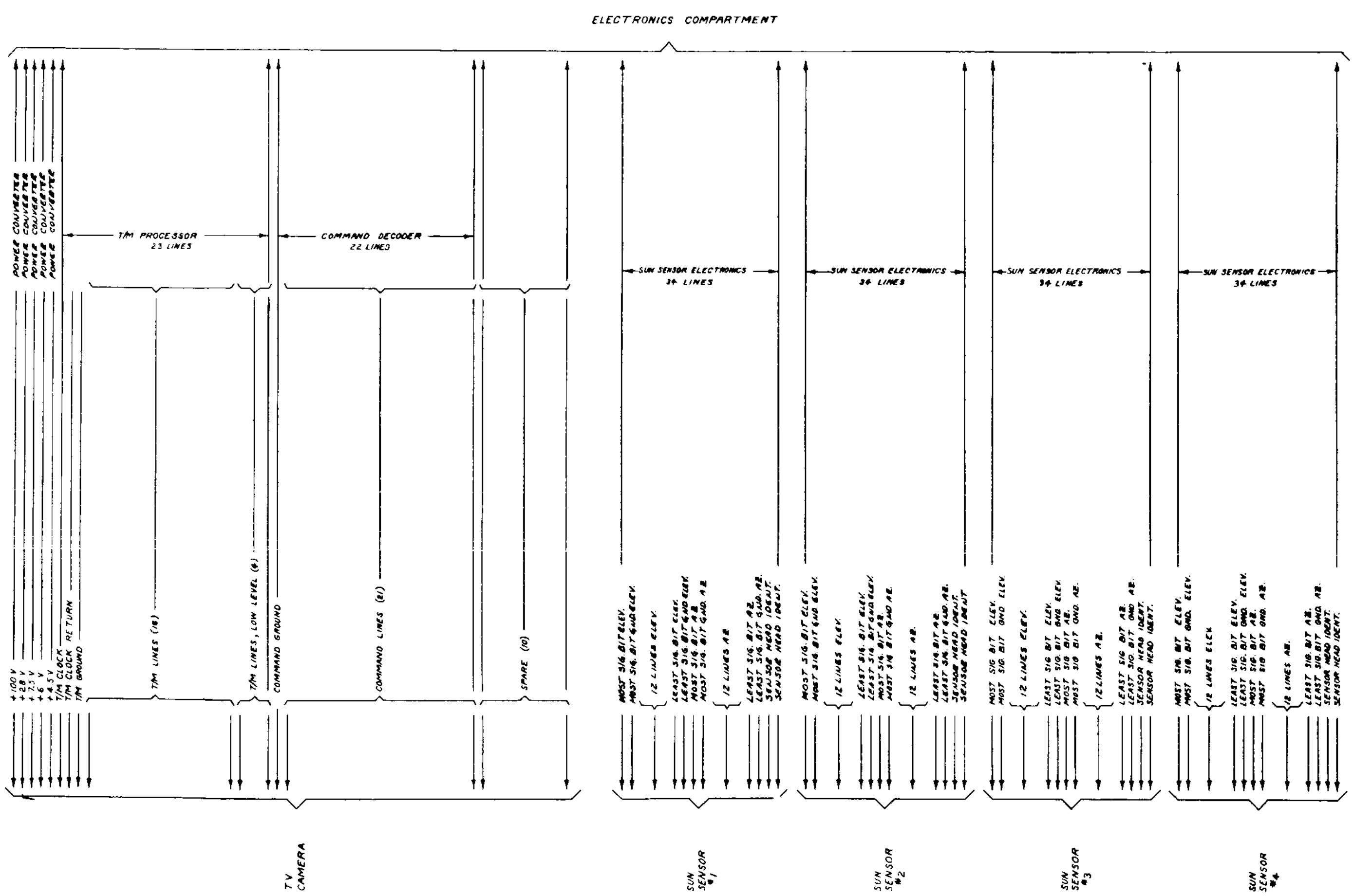


Figure 2.2-2 SLRV System Block Diagram

2


ELECTRONICS COMPARTMENT
POWER CONVERTER
T/M PROCESSOR 23 LINES
COMMAND DECODER 22 LINES
SUN SENSOR ELECTRONICS 34 LINES
SUN SENSOR ELECTRONICS 34 LINES
SUN SENSOR ELECTRONICS 34 LINES
SUN SENSOR ELECTRONICS 34 LINES
+100 V
+28 V
+6 V
T/M CLOCK
T/M CLOCK RETURN
T/M GROUND
T/M LINES (18)
T/M LINES, LOW LEVEL (5)
COMMAND GROUND
COMMAND LINES (21)
SPARE (10)
12 LINES ELEV.
12 LINES AZ.
TV CAMERA
SUN SENSOR #1
SUN SENSOR #2
SUN SENSOR #3
SUN SENSOR #4

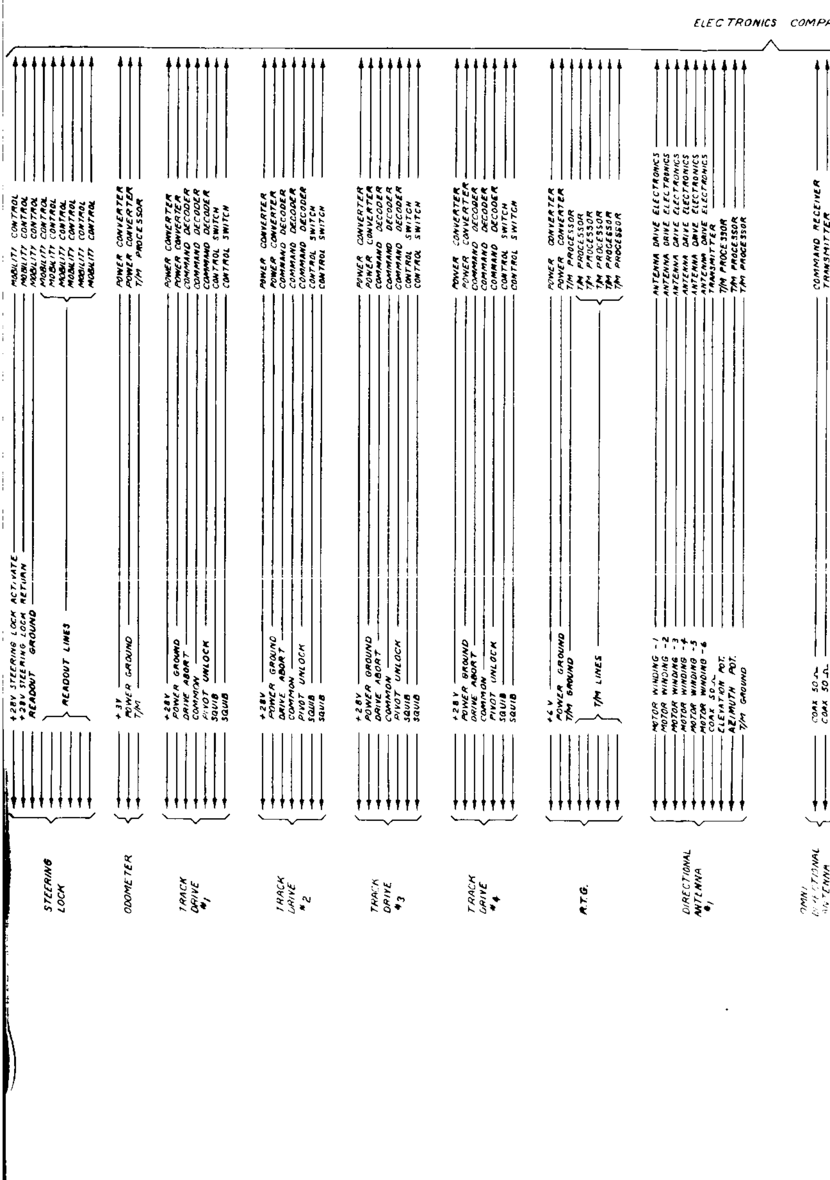
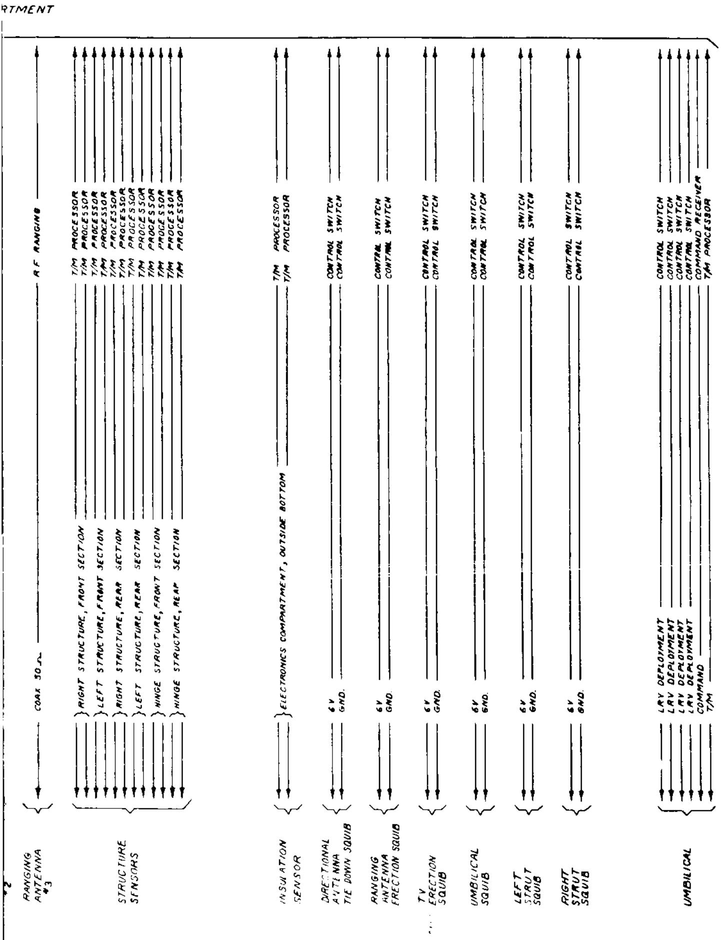
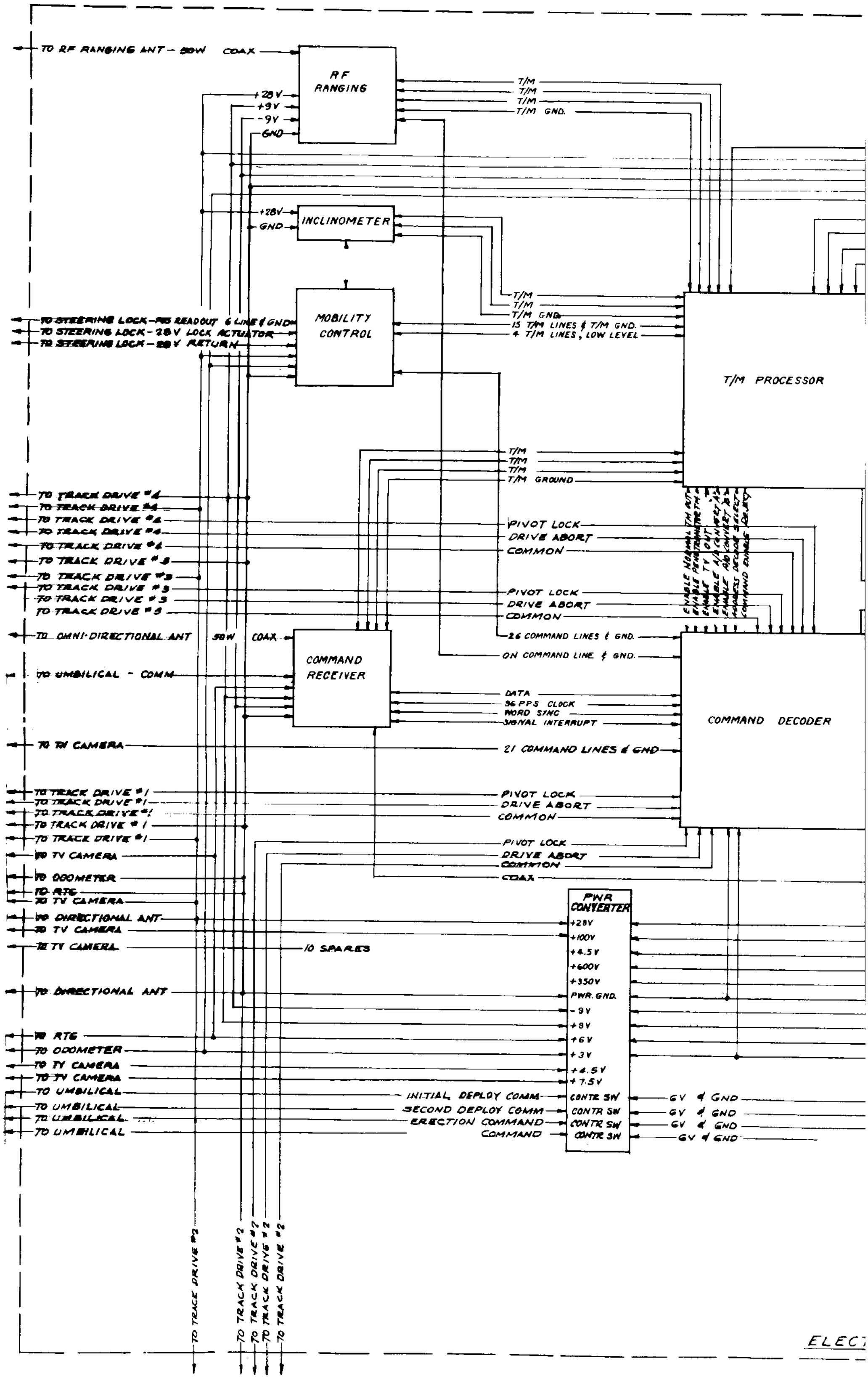

ELECTRONICS COMPA
STEERING LOCK
+28V STEERING LOCK ACTIVATE
+28V STEERING LOCK RETURN
READOUT GROUND
READOUT LINES
MOBILITY CONTROL
ODOMETER
+3V
POWER GROUND
T/M
POWER CONVERTER
T/M PROCESSOR
TRACK DRIVE #1
TRACK DRIVE #2
TRACK DRIVE #3
TRACK DRIVE #4
+28V
DRIVE ABORT
COMMON
PIVOT UNLOCK
SQUIB
COMMAND DECODER
CONTROL SWITCH
R.T.G.
+6V
T/M GROUND
T/M LINES
DIRECTIONAL ANTENNA #1
MOTOR WINDING -1
MOTOR WINDING -2
MOTOR WINDING -3
MOTOR WINDING -4
MOTOR WINDING -5
MOTOR WINDING -6
COAX 50Ω
ELEVATION POT.
AZIMUTH POT.
ANTENNA DRIVE ELECTRONICS
TRANSMITTER
OMNIDIRECTIONAL ANTENNA
COMMAND RECEIVER

Figure 2.2-3

2



SLRV Wiring Diagram


RF RANGING
INCLINOMETER
MOBILITY CONTROL
COMMAND RECEIVER
T/M PROCESSOR
COMMAND DECODER
PWR CONVERTER
TO RF RANGING ANT - 50W COAX
TO OMNI-DIRECTIONAL ANT 50W COAX
TO UMBILICAL - COMM
TO TV CAMERA
TO ODOMETER
TO RTG
TO DIRECTIONAL ANT
TO UMBILICAL
15 T/M LINES & T/M GND.
4 T/M LINES, LOW LEVEL
T/M GROUND
PIVOT LOCK
DRIVE ABORT
COMMON
26 COMMAND LINES & GND.
ON COMMAND LINE & GND.
DATA
36 PPS CLOCK
WORD SYNC
SIGNAL INTERRUPT
21 COMMAND LINES & GND
COAX
10 SPARES
INITIAL DEPLOY COMM
SECOND DEPLOY COMM
ERECTION COMMAND
COMMAND
CONTR SW
6V & GND

ELECT

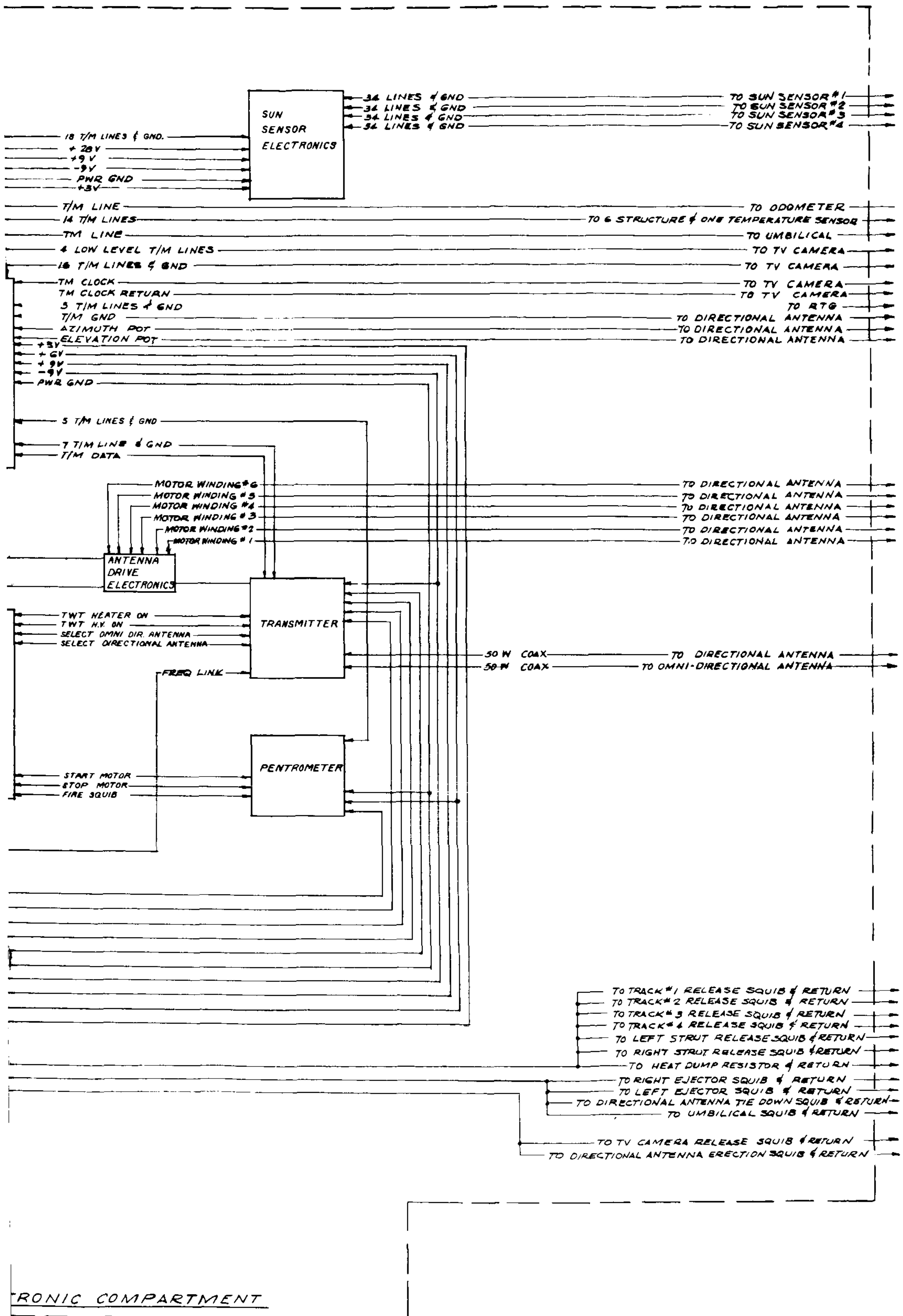


Figure 2.2-4 Thermal Box Schematic

- SURVEYOR MODIFICATION
  - Deployment Mech
  - Transponder
  - Umbilical
  - Antenna
  - Switching Logic

Figure 2.2-5 Vehicle Hardware Tree

- SLRV
  - STRUCTURE ASSY
    - Straps
    - Structure Sub Assy (Front)
    - Structure Sub Assy (Rear)
    - Suspension
    - Deployment Interface
    - Steering Lock
    - Antenna Errection Mech.
    - T. V. Errection Mech.
  - TRACTION DRIVE ASSY
    - Traction Drive Unit
    - Track Frame Assy
    - Idler Sprocket
    - Pre-Stressed Rim
    - Sector Stop Assy
    - Odometer
  - ELECTRONIC BOX ASSY
    - Thermal Plate
    - Insulation
    - Command Receiver
    - Solar Aspect Sensor Electronics
    - Transmitter
    - T/M Processor (With Sensors)
    - Converter
    - Penetrometer
    - Voltage Regulator
    - Command Decoder
    - Mobility Control
    - RF Ranging
    - Inclinometer
    - Umbilical
  - RTG

- T-V Camera Assy
  - Mounting Post
- Solar Aspect Sensors
- Antennas
  - RF Ranging
  - Omni Directional
  - Directional

Figure 2.2-6 Surveyor Modification Hardware Tree

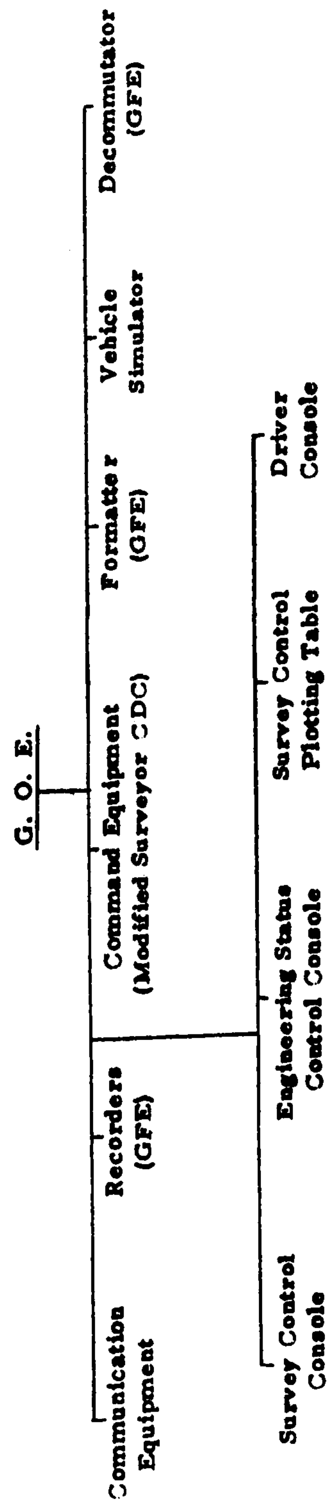


Figure 2.2-7 GOE Hardware Tree

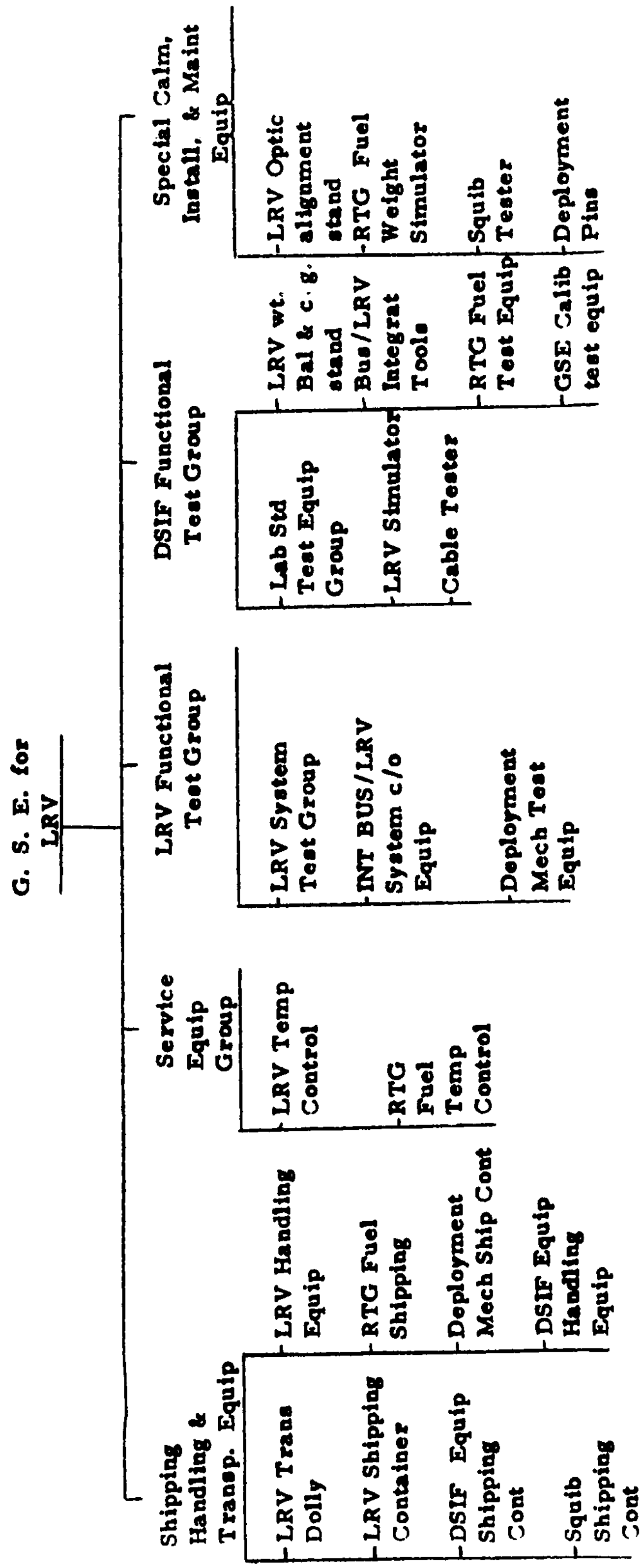
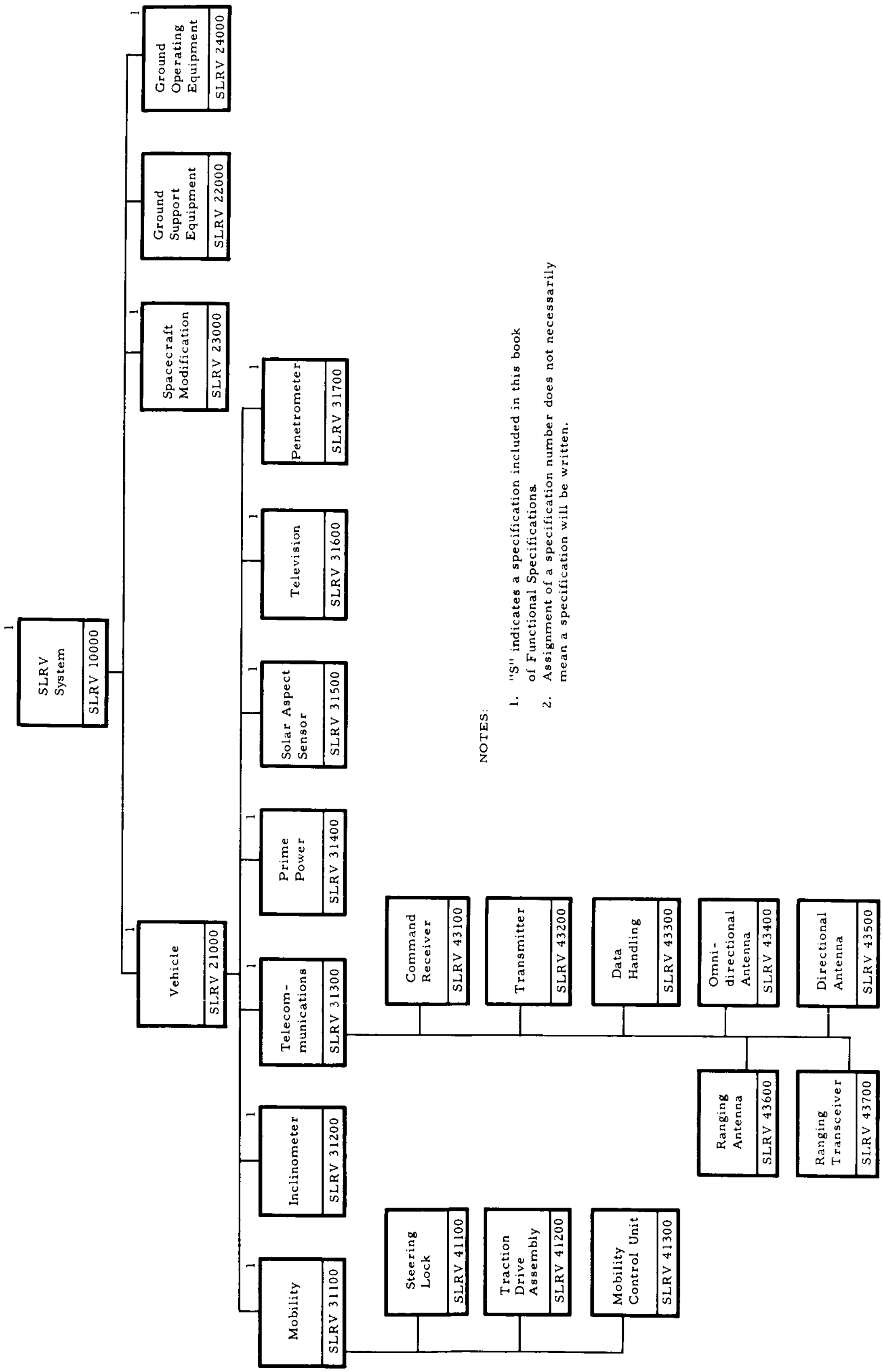


Figure 2.2-8 GSE Hardware Tree



NOTES:

1. "S" indicates a specification included in this book of Functional Specifications.
2. Assignment of a specification number does not necessarily mean a specification will be written.

Figure 2. 2-9 Functional Specification Tree

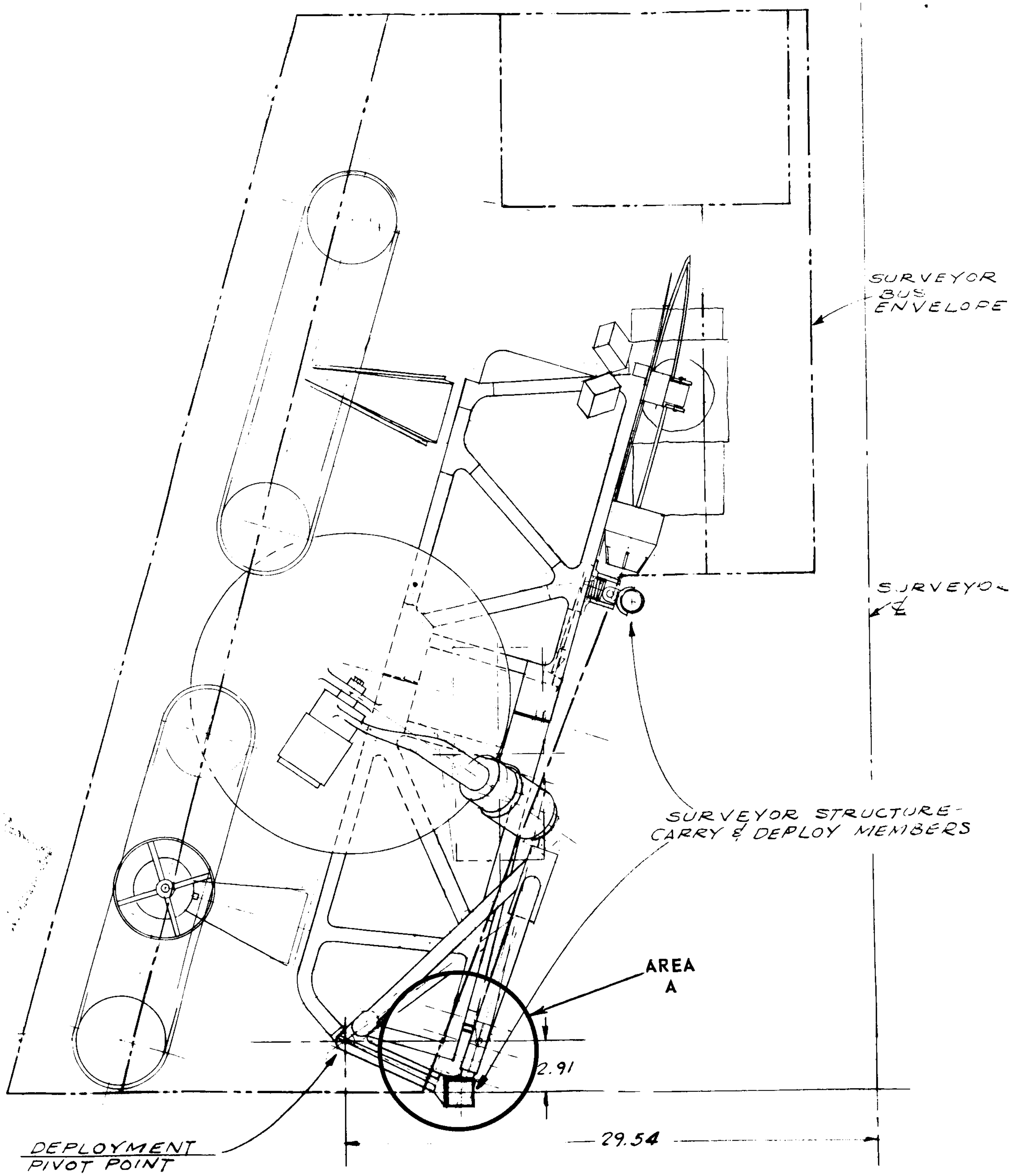


Figure 2.2-10 SLRV-Surveyor Compatibility Problem Area

The major items of the GSE system are listed below:

1. SLRV Functional Test Group
2. SLRV Transportation, Handling and Shipping Equipment
3. SLRV Servicing Equipment
4. SLRV Alignment and Calibration Equipment
5. SLRV Pre-launch Checkout Equipment Group
6. Surveyor/SLRV Umbilical Function Test Set
7. Surveyor Deployment Mechanism Test Fixture
8. Surveyor Modification Shipping Containers
9. RF Ranging Transponder Test Set
10. GOE Functional Test Equipment Group
11. GOE Handling, Transportation, and Shipping Equipment
12. SLRV Simulator.

These items and their functions are discussed in Section 2.15.

2.2.3 Ground Operating Equipment (GOE)

The GOE performs the functions of vehicle control, performance monitoring, and collection and analysis of survey data when the SLRV is operating on the lunar surface. This equipment is selected in conjunction with the vehicle to provide adequate control of the vehicle and to facilitate the flow, use, and storage of lunar data. This equipment will consist of only that equipment necessary to support the existing and planned DSIF and SFOF facilities.

The equipment at the Goldstone Deep Space Station (DSS) will consist of a Data Reconstruction Unit, a TV Data Processor, and a TV monitor.

The equipment at the SFOF will consist of an Input Signal Monitor Console, a Data Reconstruction Unit, A TV Data Processor, a Vehicle System Monitoring and Control Console, a Vehicle Control Console, Survey Control Console, a Command Decoder unit, a Command Word Generator, and photometric analysis equipment. Functional design information on the above equipment is found in Section 2.14.

2.2.4 Vehicle Weight, Balance, and Power

The total operating weight of the vehicle is 91.87 lb. The stowed total weight of the SLRV is 100 lb including Surveyor mounted equipment. The SLRV uses a transponder and the transponder antenna on the Surveyor Spacecraft for navigation. Also left behind with the Surveyor Spacecraft will be the deployment mechanisms, the radiation heat shield, and the umbilical cabling. The total SLRV weight left with the Surveyor Spacecraft is 8.13 lb. Figure 2.2-11 shows the location of Surveyor mounted equipment.

Figure 2.2-12 shows the reference axes orientation used for the center of gravity and moments of inertia calculations for the SLRV. Table 2.2-1 gives a breakdown of the components on the SLRV in the operating configuration and the weights for each component. Table 2.2-2 gives the weight breakdown for the components left on the Surveyor Spacecraft.

The location of the center of gravity has been calculated for the vehicle in its operating configuration and in the folded-for-stowage configuration. This information, together with the moments of inertia about these center of gravity locations, is summarized in Table 2.2-3.

The power furnished by the converter for each component of the vehicle system has the appropriate voltage levels required by the individual equipment units. This has been done to eliminate inefficient power converters at each unit. Equipment and operational functions have been chosen to maintain power consumption below the capacity of the power subsystem. Table 2.2-4 shows the constant power requirements for each unit, the maximum additional power that can be required by each unit, and various combinations of loads which cannot be supplied because the combined load exceeds the supply. In Table 2.2-5 are presented in detail the power requirements for each equipment unit specified by voltage level.

On the pad and during the earth-moon transit, the traction drive assemblies, the TV, the transmitter, and various other units do not consume all of the power generated by the RTG. In order to prevent overheating within the electronic units an energy dissipating resistor has been added to the assembly. This resistor is situated on the deployment tiedown and radiates to space.

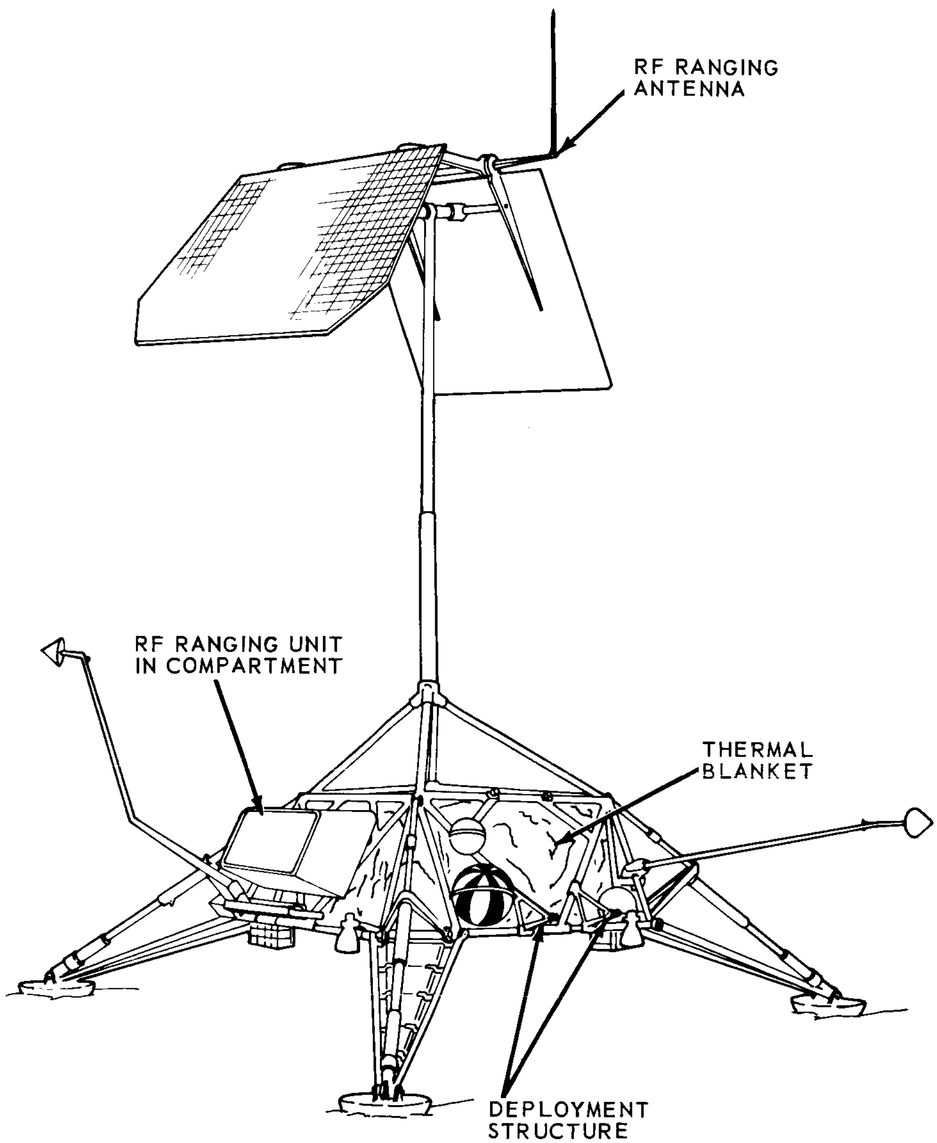


Figure 2.2-11 Location of Surveyor-Mounted Equipment

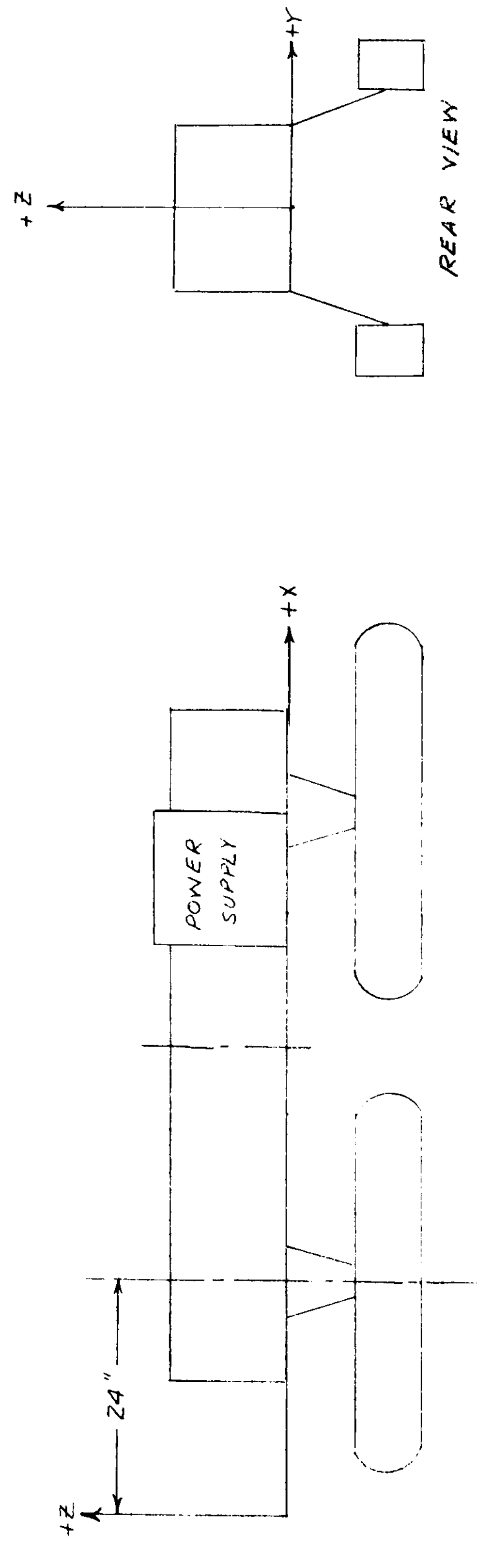


Figure 2.2-12 Reference Axes Orientation for SLRV

TABLE 2.2-1

SLRV COMPONENT WEIGHTS (OPERATING CONFIGURATION)

Electronics	(12.1)
Mobility Control	0.5
Reciever	1.4
Omni-Directional Antenna	1.0
Transmitter	3.2
Directional Antenna Elect.	0.5
Directional Antenna & Servos	4.0
Dir., Ant. Boom & Mech.	1.5
Navigation and Control	8.3
RF Ranging	3.5
RF Ranging Antenna	0.5
Inclinometer	1.0
Odometer	0.4
Sun Sensor Elect.	1.5
Sun Sensor & Hardware	.35
Sun Sensor & Hardware	.35
Sun Sensor & Hardware	.35
Sun Sensor & Hardware	.35
Data Handling	(2.75)
Command Decoder	0.25
Telemetry	2.50
Power Supply	(24.6)
RTG	20.9
Converter	3.7
Experiments	(2.6)
Penetrometer	2.6
Television	(8.45)
Camera and Motor	7.63
Camera Support & Mech.	.82
Mobility	(12.9)
Track 1	3.0
Track 2	3.0
Track 3	3.0
Track 4	3.0
Steering Lock	0.9
Cabling	(4.5)
Thermal Control	(4.50)
Thermal Box	2.25
Thermal Plate	2.25
Structure	(7.424)
Body Half 1	2.85
Body Half 2	3.129
Suspension System 1	.720
Suspension System 2	.720
Contingency	3.75
Operating Vehicle Totals	91.87

TABLE 2.2-2

SLRV FINAL COMPONENT WEIGHT (STOWED CONFIGURATION)

Units	Weight
Spacecraft	(8.13)
Deployment	3.63
Umbilical	0.5
Transponder	1.0
Transponder Antenna	0.2
Transponder Support	0.5
Coaxial Cable	0.5
Radiation Heat Shield	2.50

TABLE 2.2-3

CENTER OF GRAVITY AND INERTIA TABLE FOR STOWED AND OPERATING CONFIGURATIONS

Center of Gravity (Ref. Figure 2.2-12)

	x	y	z
Operating	39.58	-.026	6.89
Stowed	35.38	1.11	5.38

Interia About cg (slugs -ft^2)

	I_{xx}	I_{yy}	I_{zz}
Operating	3.62	3.76	3.78
Stowed	1.70	2.51	3.52

TABLE 2. 2-4

CONVERTER OUTPUT POWER DISTRIBUTION (A)

Constant (Fixed) Loads:

Mobility:	Control Motors	0. 2 W (+. 18 AC)
Communications:	Transmitter	1. 13
	Trans. Antenna	----
	Receiver	1. 4
	Television	3. 17
Penetrometer:		0. 07
Navigation:	RF Ranging	----
	Inclindmeter	----
	Sun Sensor	0. 395
	Odometer	0. 1
Data Handling:	TM Processor	2. 94
	Command Decoder	1. 1
Regulators:		1. 323
	TOTAL	13. 728 W (+. 18 WAC)

Additional (Switched Or Variable) Loads:

▨ = Mode Not Feasible

	Mobility (Control & Motors)	Transmitter	Trans. Antenna	Television	Penetrometer	RF Ranging
Mobility (Control & Motors)	9. 8	17. 16	14. 0	12. 02	12. 43(14. 0^{c})	11. 2
Transmitter	17. 16	7. 36	13. 36	11. 38	11. 79(13. 36^{c})	10. 56
Trans. Antenna	14. 0	13. 36	6. 0	10. 02	10. 43(12. 0^{c})	9. 2
Television	12. 02	11. 38	10. 02	4. 02	8. 45(10. 02^{c})	7. 22
Penetrometer	12. 43(14. 0^{c})	11. 79(13. 36^{c})	10. 43(12. 0^{c})	8. 45(10. 02^{c})	4. 43(6. 0^{c})	7. 63(9. 2^{c})
RF Ranging	11. 2	10. 56	9. 2	7. 22	7. 63(9. 2^{c})	3. 2

Does Not Include Coaxial Relay

2.2.5 RTG and Vehicle Integration

2.2.5.1 Thermal Interfaces

The radiation design considered optimum for the RTG may impose thermal control problems on the other parts of the vehicle. During the lunar day, heat must be dissipated from the instrumentation package, and thermal radiation shielding is required. However, during lunar night conditions, thermal energy must be supplied to the instrumentation package for temperature control. Thus, it is desirable to use the thermal radiation from the RTG to satisfy this demand directly rather than using the electrical power (which is limited in quantity) as a heat source.

During prelaunch, cooled air will be supplied to the shroud to cool the SLRV. During transit, the RTG can dissipate heat to space after the shroud is ejected which will occur approximately 3.5 minutes from launch. A special thermal shield will also aid in protecting the Surveyor spacecraft from the heat of the RTG.

2.2.5.2 Electrical Interface

The RTG is basically a constant power device, and serious performance degradation can result to the thermoelectric generator if numerous load variations are imposed. This does not preclude periodic load changes, but radically fluctuating loads can cause detrimental thermal cycling of the thermoelectric material. This is prevented by proper design of the power converter and regulator. Another consideration in converter-regulator design is to ensure that the generator is not open circuited for long periods, since this will result in loss of Peltier cooling at the hot junction with no current flow. In addition, the generator surface must radiate a greater thermal flux, since no conversion to electricity is occurring with an open-circuit condition.

The electrical interface between the RTG and the converter-regulator consists of two insulated leads.

2.2.5.3 Power Integration with Subsystems

Subsystem integration involves the load requirements of all subsystems, the operation of the RTG and its control, and the operation of the converter-regulator and its characteristics.

	Mode 1			Mode 2				Mode 3			
	Mobility			Communications				Penetrometer			
Voltage And Tolerance	Control	Motor	Transmitter	Receiver And Antenna	Transmitter	Transmitter Antenna	Television	Motor	Transmitter	RF Ranging	Incl
4.5VDC ± 5%	----	----	1.13[A]	----	1.13[A]	----	----	----	1.13[A]	----	---
7.5 VDC ± 0.1%	----	----	----	----	----	----	0.04[A]	----	----	----	---
6 VDC ± 5%	----	----	----	----	----	----	0.6[A]	----	----	----	---
6 VDC ± 1 %	----	----	----	0.2[A]	----	----	----	0.07[A]	----	----	---
9 VDC ± 1%	----	----	----	0.2[A]	----	----	----	----	----	1.75[D]	---
4.5 VDC ± 5%	----	----	----	----	----	----	2.02	----	----	----	---
350 VDC +10 -5 %	----	----	6.05	----	6.05	----	----	----	6.05	----	----
600 VDC ± 10%	----	----	1.2	----	1.2	----	----	----	1.2	----	----
3 VDC ± 10%	0.2[A] (+.18 WAC)	----	----	----	----	----	----	----	----	----	----
-9 VDC ± 5%	----	----	0.1	1.0[A]	0.1	----	----	----	0.1	0.85	----
28 VDC ± 5%	1.8	8.0	----	----	----	6.0[B]	1.9[A] 3.9[B]	4.43 (6.0[C])	----	0.6[E]	1.9
100 VDC ± 10%	----	----	0.01	----	0.01	----	0.63[A]	----	0.01	----	----
Variable Load	1.8	8.0	7.36	----	7.36	6.0[B]	4.02	4.43 (6.0[C])	7.36	3.2	----
Constant Load	0.2 (+.18WAC)	----	1.13	1.4	1.13	----	3.17	0.07	1.13	----	1.9
Subsystem Total	2.0 (+.18WAC)	8.0	8.49	1.4	8.49	6.0[B]	7.19	4.50 (6.07[C])	8.49	3.2	1.9

A = Constant Load

B = Only During Antenna Orientation

C = Peak Load

D = Required At ± 0.1 %

E = Required At ± 1 %

/

BSR

TABLE

CONVERTER OUTPUT PC

Navigation			Data Handling		Regulators	Load Conditio
nometer	Sun Sensor	Odometer	TM Proc.	Command Decoder		F-Fixed S-Switch V-Varia
	----	----	----	----	----	F
	----	----	0.18^A	----	0.165^A	F
	----	----	----	----	0.5^A	F
	----	----	1.0^A	----	0.068^A	F
	0.18^A	----	0.05^A	----	0.09^A	F,S
	----	----	----	----	----	S
	----	----	----	----	----	S
	----	----	----	----	----	S
	0.03^A	0.1^A	1.49^A	1.1^A	----	F
	0.045^A	----	0.22^A	----	----	F,S
	0.14^A	----	----	----	0.5^A	V
	----	----	----	----	----	F.S
	----	----	----	----	----	
	0.395	0.1	2.94	1.1	1.323	
	0.395	0.1	2.94	1.1	1.323	

903

2.2-5

)WER DISTRIBUTION (B)

ı	Total Power			
·d ·le	Fixed Load	Mode 1	Mode 2	Mode 3
	1.13	1.13	1.13	1.13
	0.385	0.385	0.385	0.385
	1.1	1.1	1.1	1.1
	1.338	1.338	1.338	1.338
	0.52	0.52	0.52 (2.27)	0.52
	----	----	(2.02)	----
	----	6.05	6.05	6.05
	----	1.2	1.2	1.2
	2.92 (+.18WAC)	2.92 (+.18WAC)	2.92 (+.18WAC)	2.92 (+.18WAC)
	1.265	1.365	1.365 (2.215)	1.365
	4.44	14.24	10.44	10.44
	0.63	0.64	0.64	0.64
	13.728 (+.18WAC)			
		31.068	27.268	27.268

3

The converter supplies all the desired voltage levels to all the information subsystems. The sources of possible interference are RFI generation and line voltage modulation. Conducted RFI will be reduced with filters on the converter input and converter outputs. This also reduces line radiation. A source of radiation RFI is the magnetic components; these will be mounted within a steel container. Another source of interference between subsystems results from, modulating loads; each load will be allowed a maximum line ripple voltage. Presently there are three areas of concern: (1) the TV converter at 20 kcp, (2) the A/D converter reference, and (3) mobility.

The area of interference due to momentary overloads or permanent overloads is also important. The characteristic of the RTG and the degree of overload may reduce the output voltages such that detection and removal of the overload is very difficult, especially if the logic is also lost.

2.2.5.4 Mechanical Interfaces

The RTG is packaged on the aft section of the vehicle as shown in Figure 2.2-1. When stowed aboard the Surveyor, it will present a maximum area for radiation to space. It will also be insulated from the structure of the SLRV aft section. This installation is shown in Figure 2.2-13(c).

2.2.6 Thermal Control Subsystem Integration

The thermal control on the SLRV is a passive system. This control is achieved by use of an insulated electronics compartment, thermal radiation shields, and selective thermal coatings.

To obtain thermal control, the electronic package is insulated from, but in close proximity to the RTG. The electrical heat dissipating components are mounted onto the specially designed thermal plate of the electronic package. The mounting plate is insulated from the rest of the structure. The sides, front, rear, and bottom of the package have radiation shields, and thermal coating are used on all the surfaces.

2.2.7 TV Camera Integration

2.2.7.1 Mechanical Considerations

The TV must be mounted rigidly to the structure on the front of the vehicle so as to look forward during running and be able to examine the track tread at close range. Consideration of the structure design was given so that the camera would be located 35 in. above the ground during operation on the lunar surface and also be free to turn $\pm 200^{\circ}$ in azimuth and $+15^{\circ}$ and -45° in elevation.

In order to stow the SLRV in the configuration shown in Figure 2.2-1 the TV camera is mounted on a folding boom. The camera is erected by a torsion spring upon command and released by a redundant explosion squib actuator. The TV interface on the TV boom with the vehicle structure is shown in Figure 2.2-14.

2.2.7.2 Electrical Interfaces

The electrical interfaces between the electronics compartment and the TV subsystem consist of a cable of 50 leads. These leads are shown in the SLRV electrical interface drawing (Figures 2.2-3 and 2.2-4).

2.2.7.3 Thermal Interfaces

The TV camera is physically separated from the rest of the SLRV thermal control system. Therefore, the thermal control must be integrated with the mechanical packaging of the TV electronics (Figure 2.2-15).

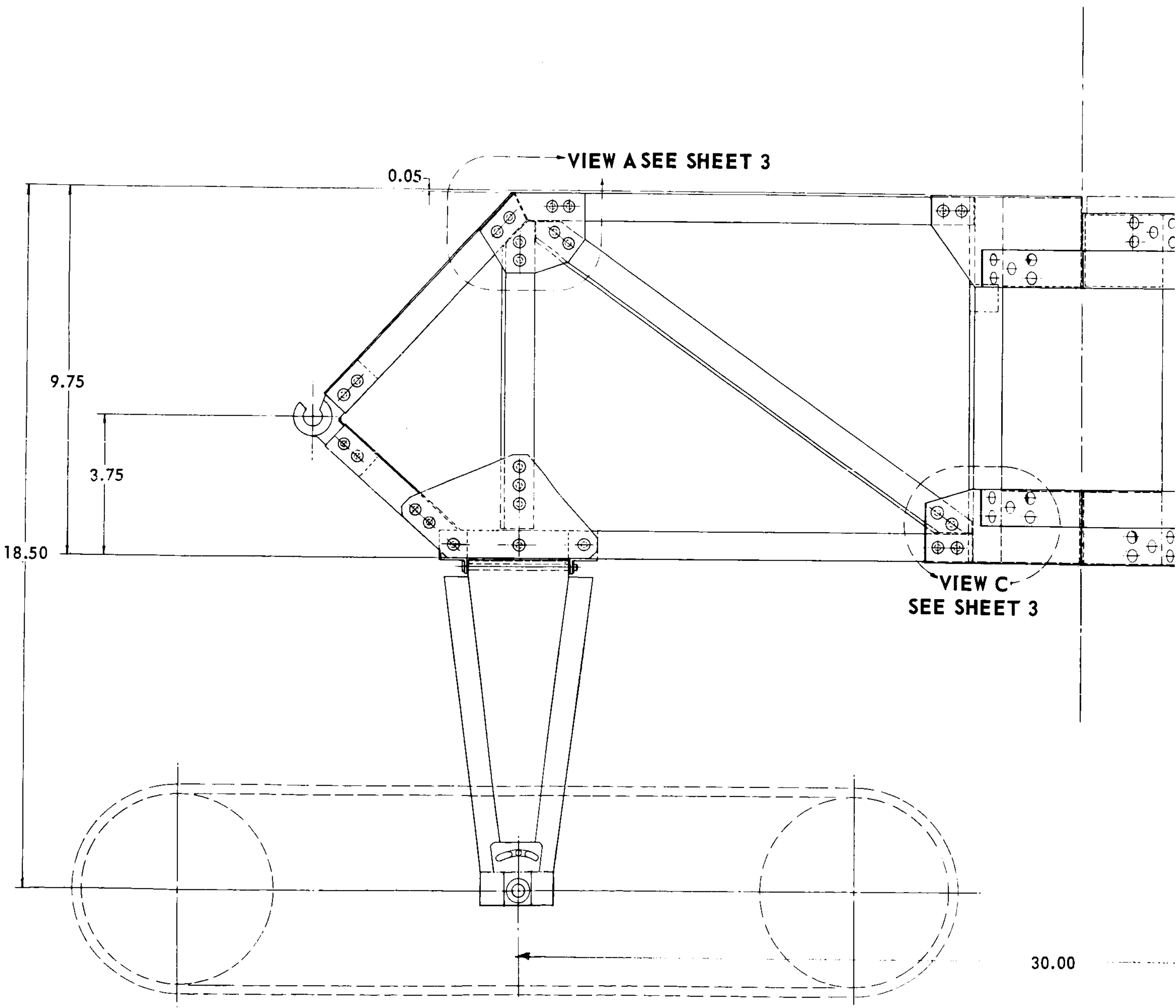
2.2.8 Structure Integration

2.2.8.1 Mechanical Considerations

The vehicle structure must be capable of supporting the other subsystems under the environments specified in Specification HAC 239503, Rev. C, Surveyor Basic Spacecraft.

The primary structure is a riveted aluminum alloy truss as shown in Figure 2.2-13 (a, b, and c).

On this structure, folding mechanisms are provided for the antenna designs. A folding and lock mechanism is also provided for the TV support mast. These devices are shown in Figure 2.2-14.



VIEW A SEE SHEET 3
0.05
9.75
3.75
18.50
VIEW C
SEE SHEET 3
30.00

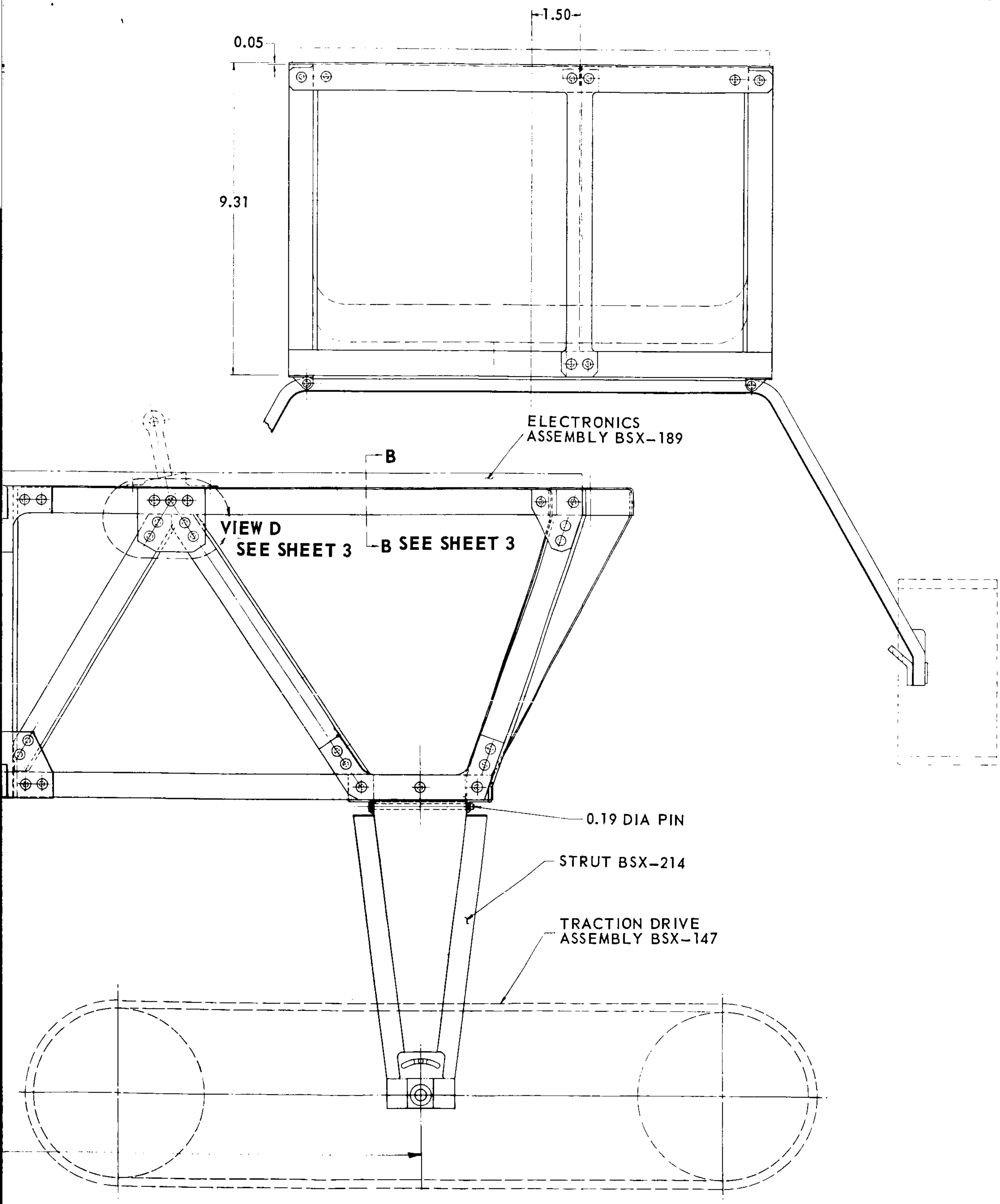
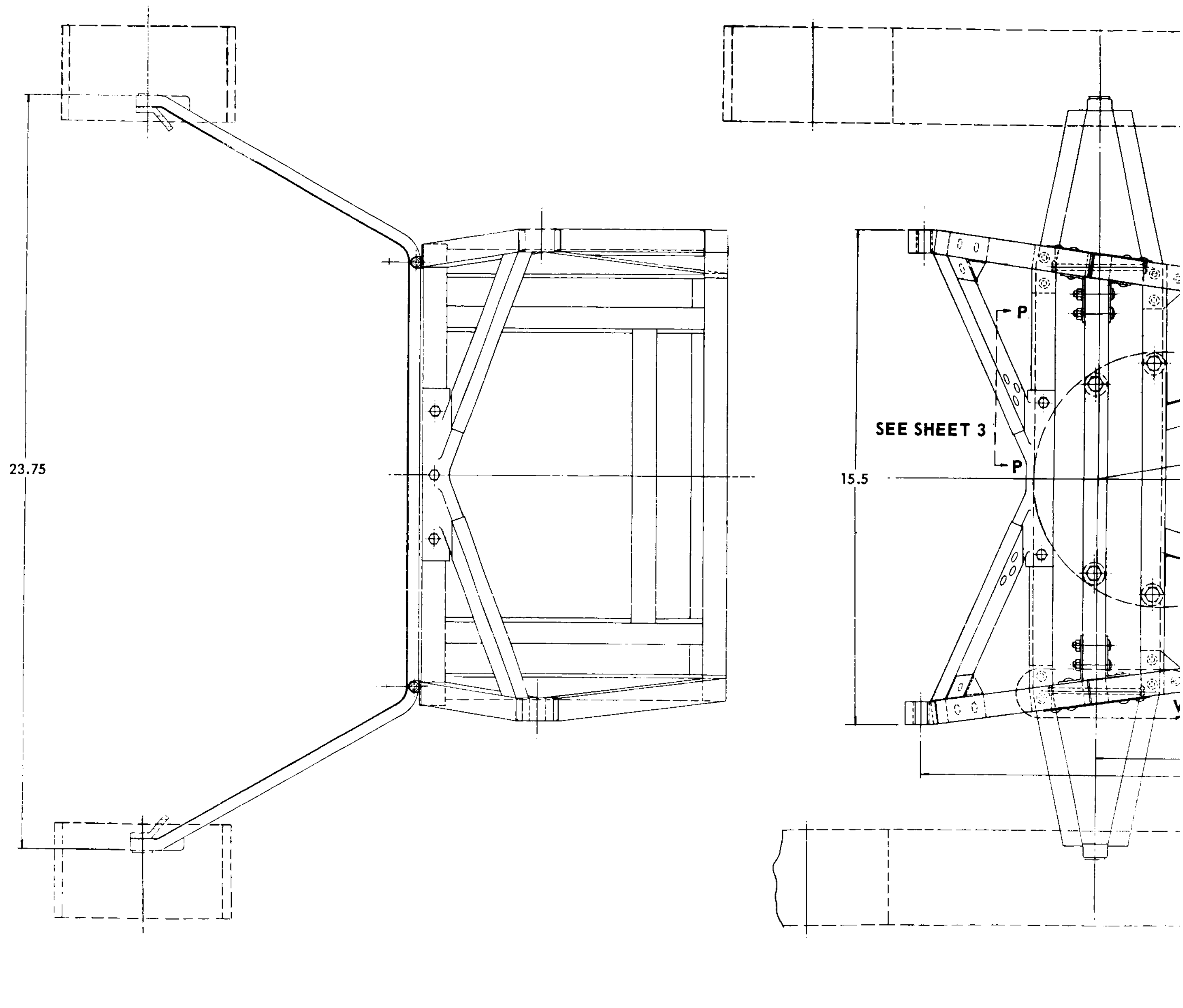


Figure 2. 2-13 SLRV Structure Assembly (Sheet 1 of 3)

2


23.75
SEE SHEET 3
P
P
15.5

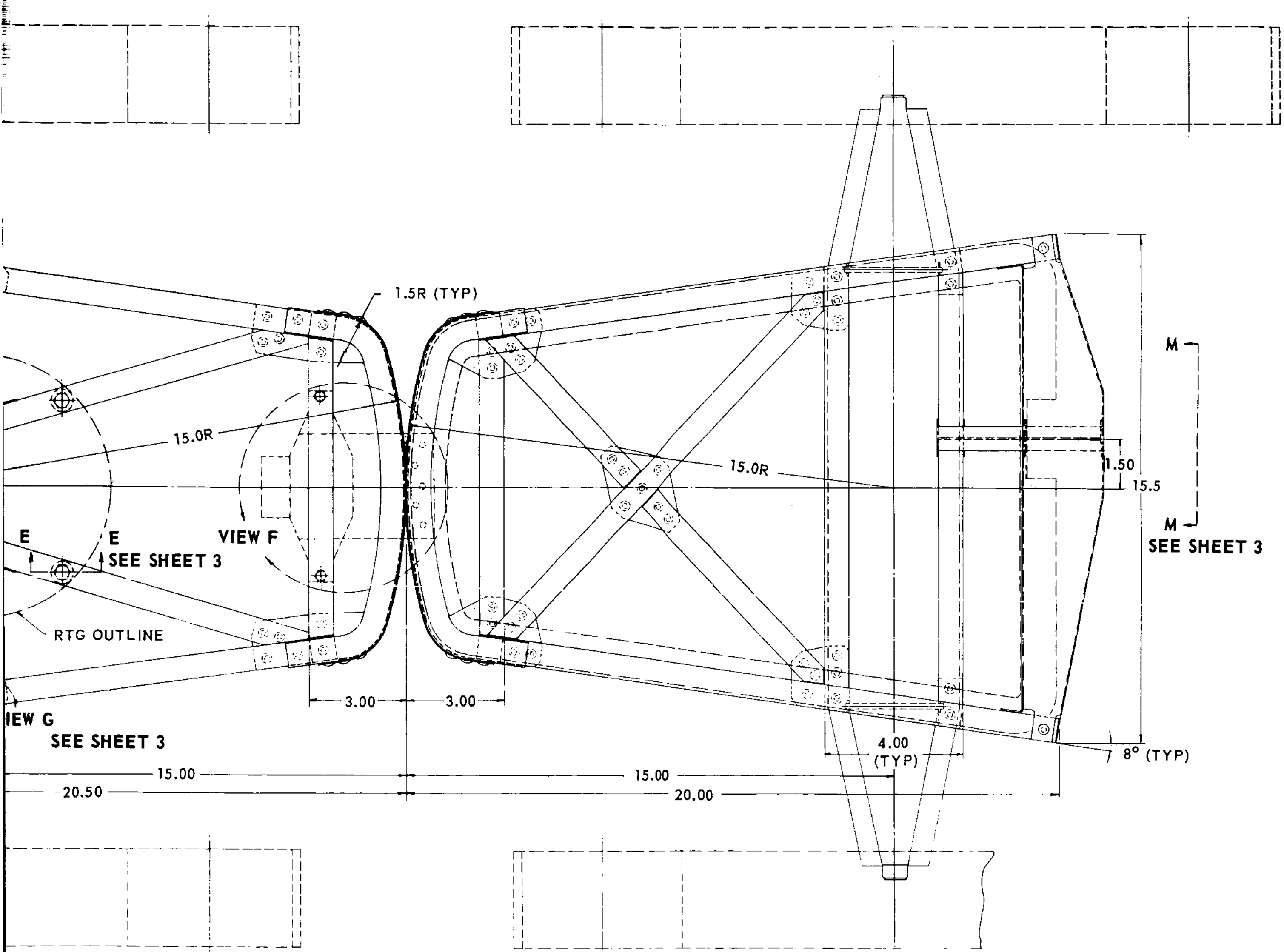
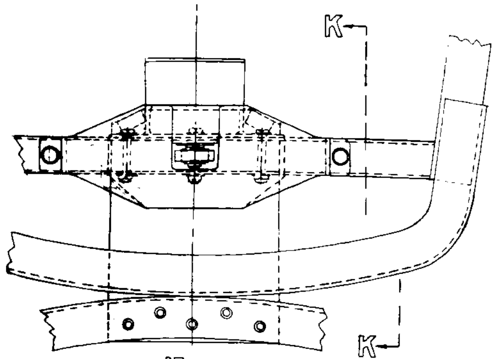
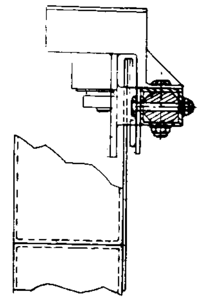


Figure 2. 2-13 SLRV Structure Assembly (Sheet 2 of 3)

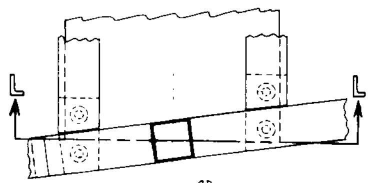
2



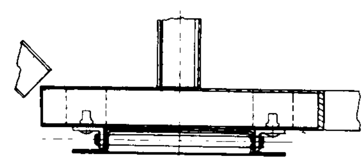
VIEW F   STEERING LOCK DETAIL



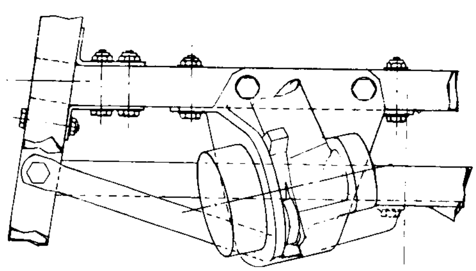
SECTION K-K

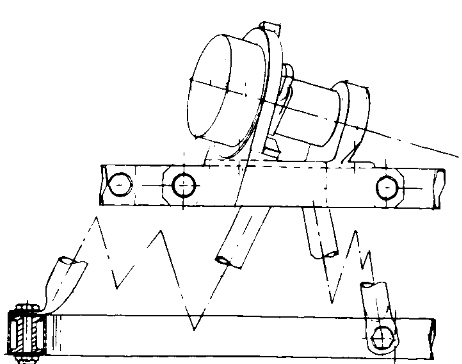


VIEW G
STRUT ATTACHMENT

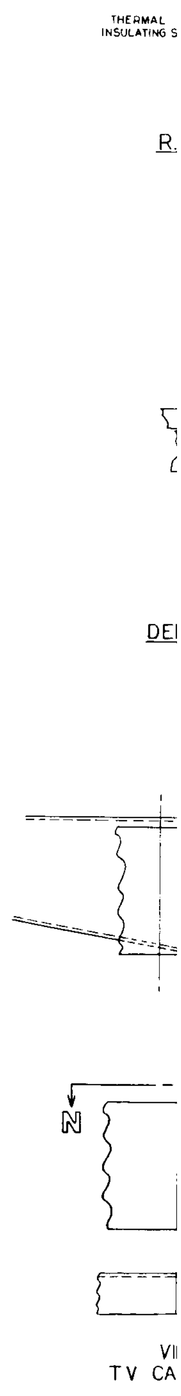


SECTION L-L





VIEW P-P



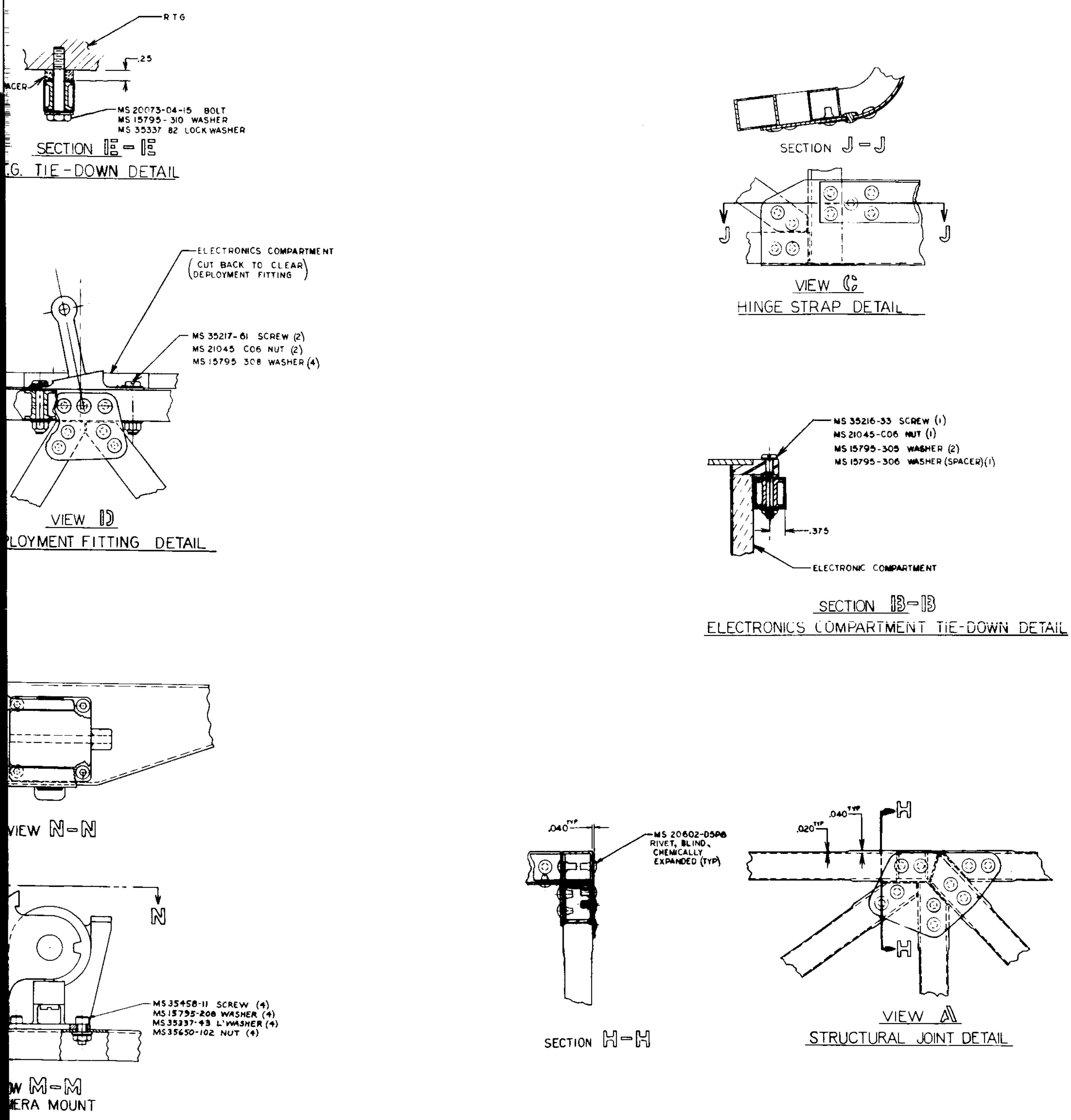


Figure 2.2-13 SLRV Structure Assembly (Sheet 3 of 3)

2

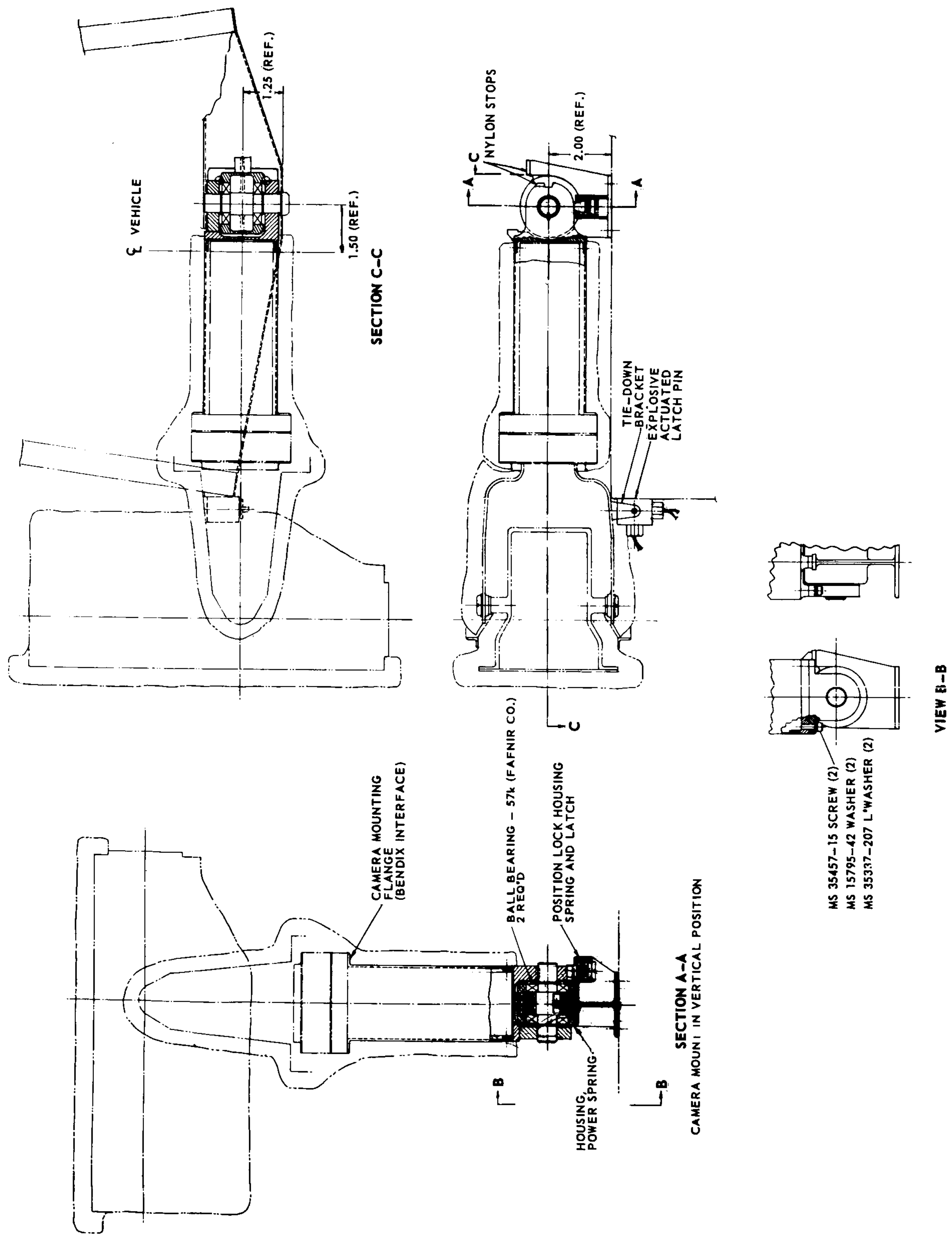


Figure 2.2-14 TV Camera Erection Mechanism

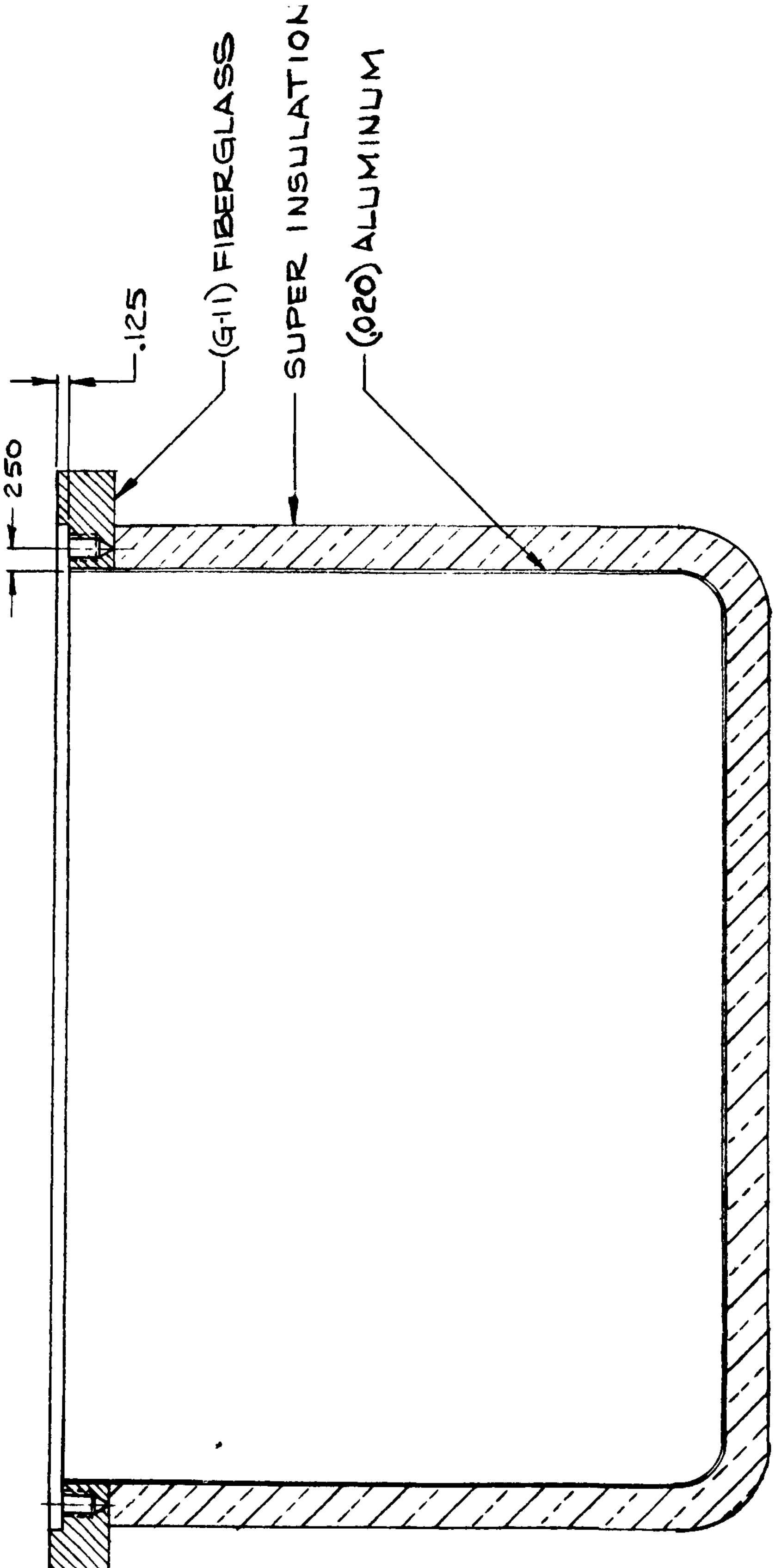


Figure 2.2-15 Thermal Box Construction

A locking device is included in the SLRV structure to align the two body sections in three positions.

Support struts are provided for attaching the traction drive units to the primary structure. The mechanical interface is shown in Figure 2.2-1. The electrical interface with the tracks and drive motors is shown in the electrical interface drawing (Figure 2.2-3).

2.2.8.2 Deployment Considerations

The deployment mechanism is shown in Figure 2.2-16. It consists of hinging the SLRV to the Surveyor structure and holding it compressed against a deployment spring by means of a squib actuated pinned locked fitting. The support hinges attach to the rear of the SLRV and to the Surveyor spacecraft structure to take the major loads and provide a pivot for deployment.

Provision for activating the deployment mechanism is made through the SLRV-Surveyor umbilical connector. Upon receipt of the command, the squib actuator releases the pinned lock fitting and allows the ejector spring to rotate the vehicle through its deployment arc. The single action release will also separate the umbilical connection from the Surveyor.

The umbilical plug for the SLRV will be located adjacent to the upper tiedown release fitting on the Surveyor Spacecraft frame. The umbilical plug will be engaged by installation of the SLRV in Surveyor and released by separation of the SLRV.

Present design calls for only six electrical leads in the plug—four to control SLRV deployment and two for command and telemetry signals. The deployment signals will be the on-off type to activate squib circuits using power from the SLRV. It may be desirable for reliability to add backup circuits using Surveyor power. The command and telemetry leads would probably be shielded. It appears possible from the SLRV block diagram to connect at a point between the SRLV telemetry processor and transmitter, thus supplying processed signals through the umbilical to the Surveyor for relay both during prelaunch on the pad and in transit.

2.2.9 Antenna Integration

2.2.9.1 Mechanical Interface

The transmitting and receiving antennas are mounted on folding booms to stow in the available envelope and provide the desired operational height after deployment. These units are erected by torsion springs and locked into position mechanically. The deployment command initiates this action immediately following the erection of the TV by the delayed spring of a redundant squib actuator. The directional antenna interface is shown in Figure 2.2-17..

2.2.9.2 Electrical Interfaces

The electrical interfaces to the transmitting, receiving, and RF ranging antennas are shown in the electrical interconnecting diagram, Figure 2.2-3.

2.2.10 Penetrometer Integration

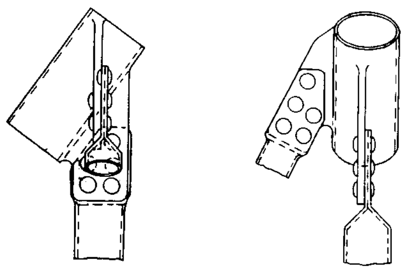
The penetrometer is located with its bottom face at the 10.75-in. ground clearance height and free from all obstruction. This unit is located close to the cg to permit use of the maximum size head on the penetrometer. The loacation is also selected so that the penetrometer measurements are not made in the track path. Figure 2.2-1 shows the mechanical installation of the equipment.

2.2.10.1 Electrical Command Signal

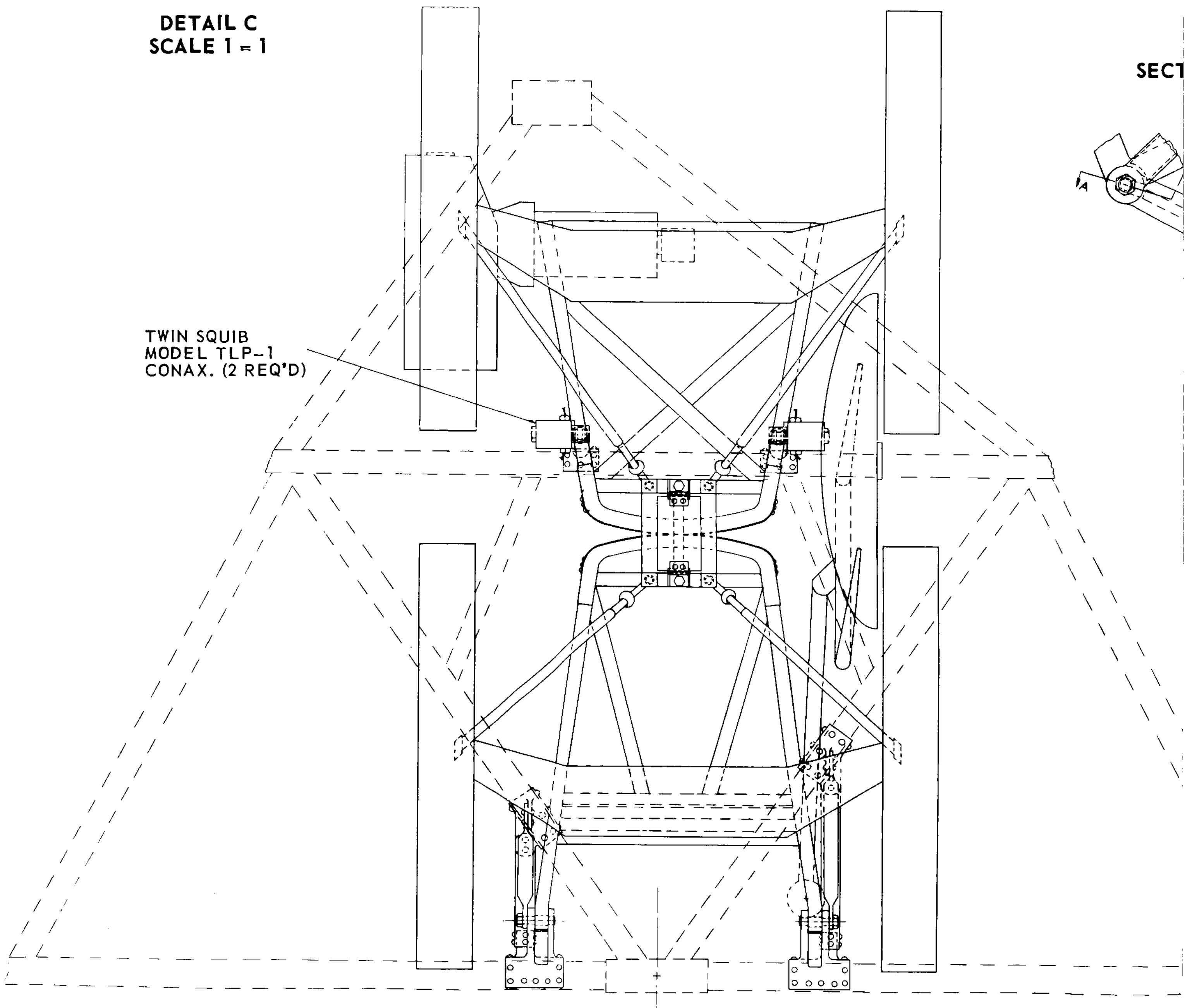
The command signal required to initiate a signal phase of operation of the penetrometer will be a 28-volt positive pulse with a time duration of 10 milliseconds or greater. Two other command pulses will be necessary; one to provide an override signal to stop and retract the probe during the operation cycle, and another to initiate the explosive charge destroying the tube.

Voltage Requirements

The penetrometer mechanism required two voltage supplies including one 28-volt supply for the DC motor and one regulated 6-volt supply for the instrumentation and control circuits.



DETAIL C
SCALE 1 = 1



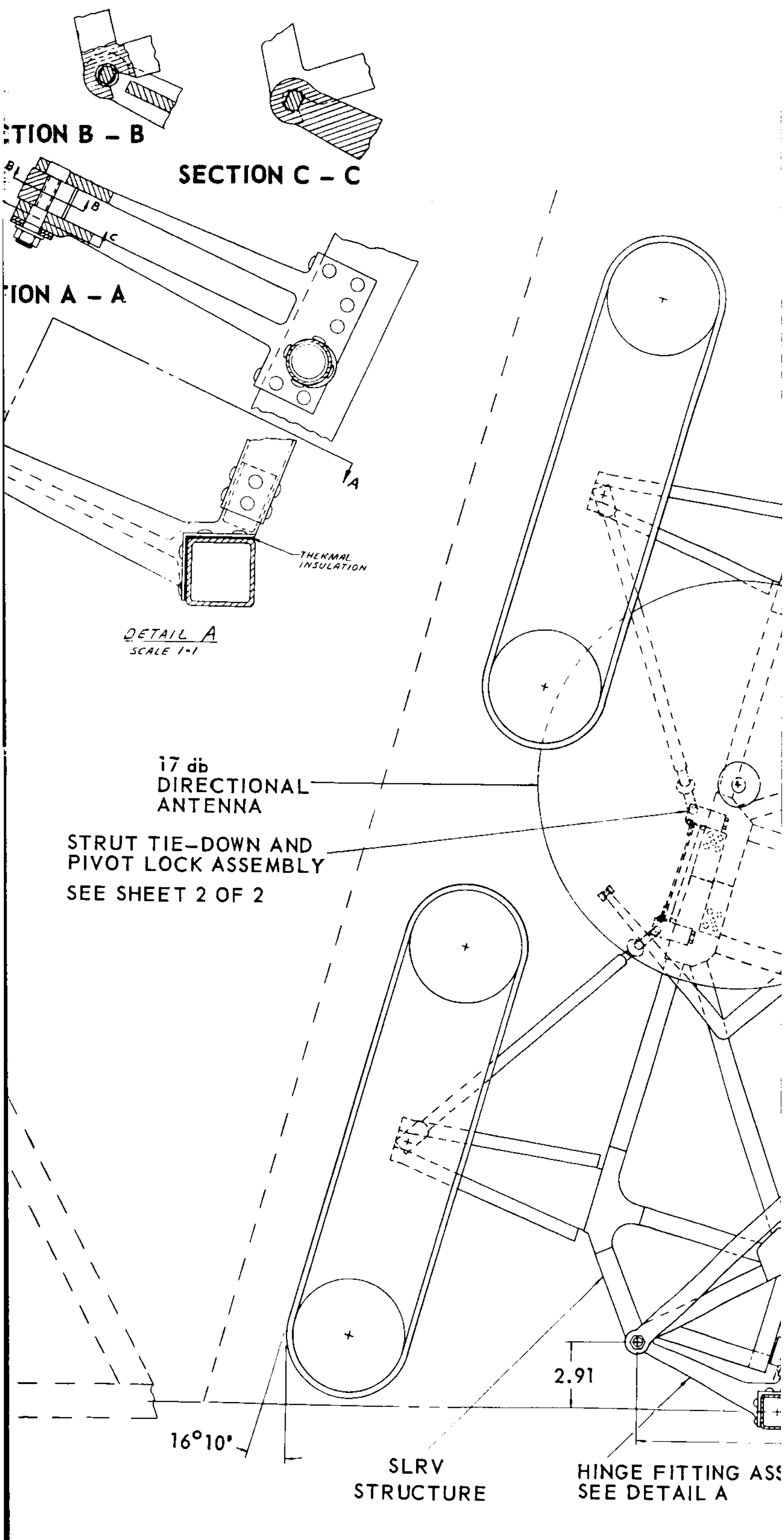
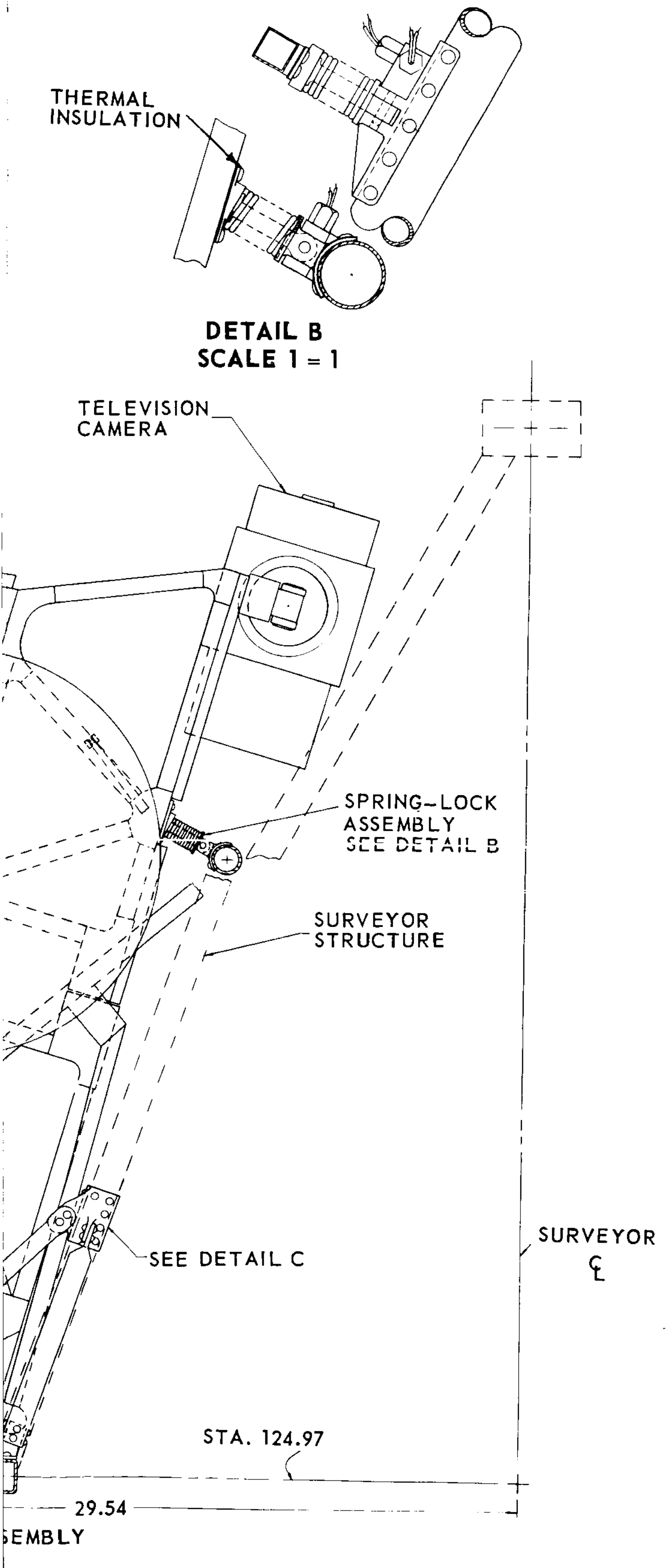
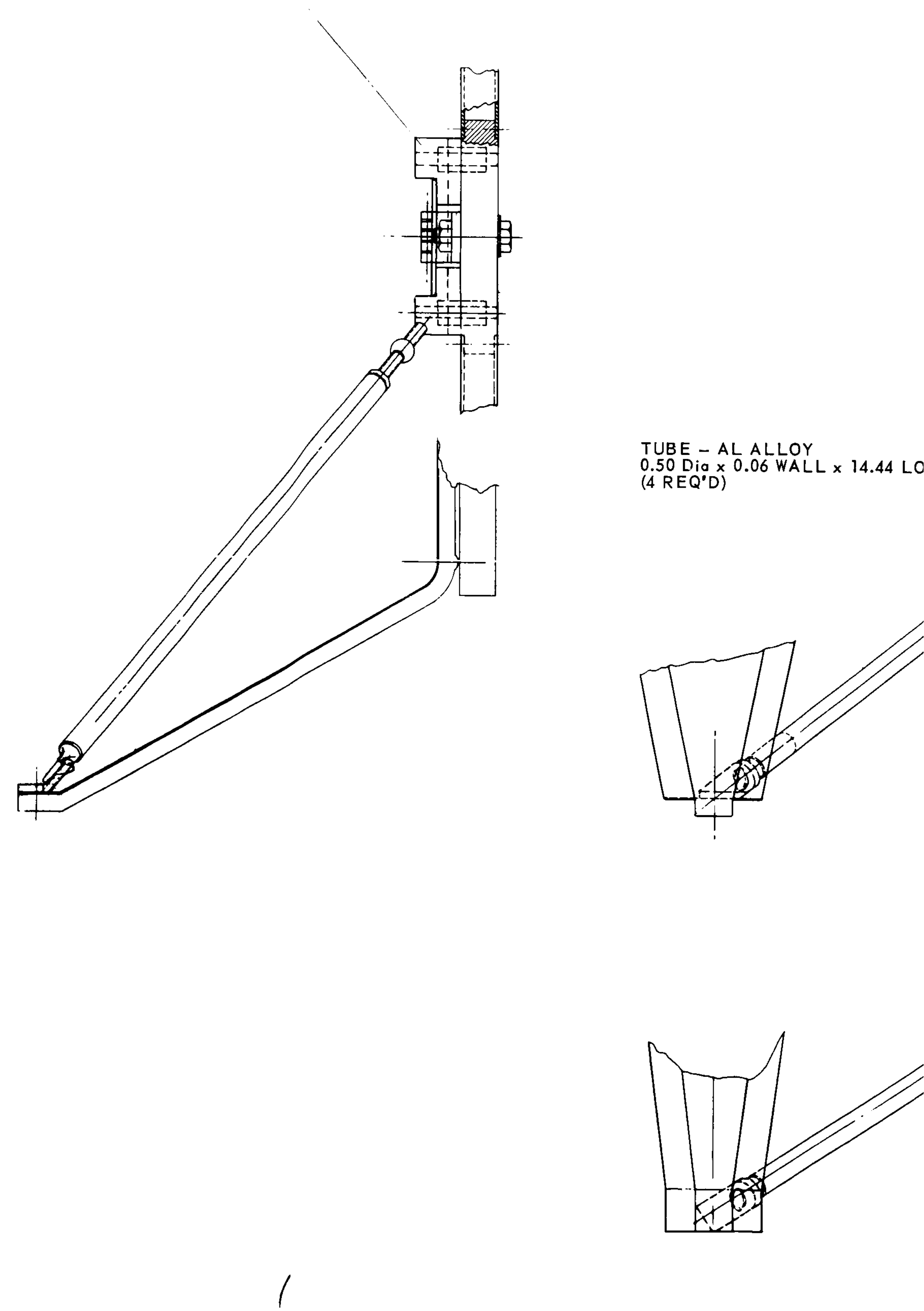


Figure 2.2-16(a) SLRV Deployme

2


THERMAL
INSULATION
DETAIL B
SCALE 1 = 1
TELEVISION
CAMERA
SPRING-LOCK
ASSEMBLY
SEE DETAIL B
SURVEYOR
STRUCTURE
SEE DETAIL C
SURVEYOR
℄
STA. 124.97
29.54
SEMBLY


TUBE – AL ALLOY
0.50 Dia x 0.06 WALL x 14.44 LO
(4 REQ'D)

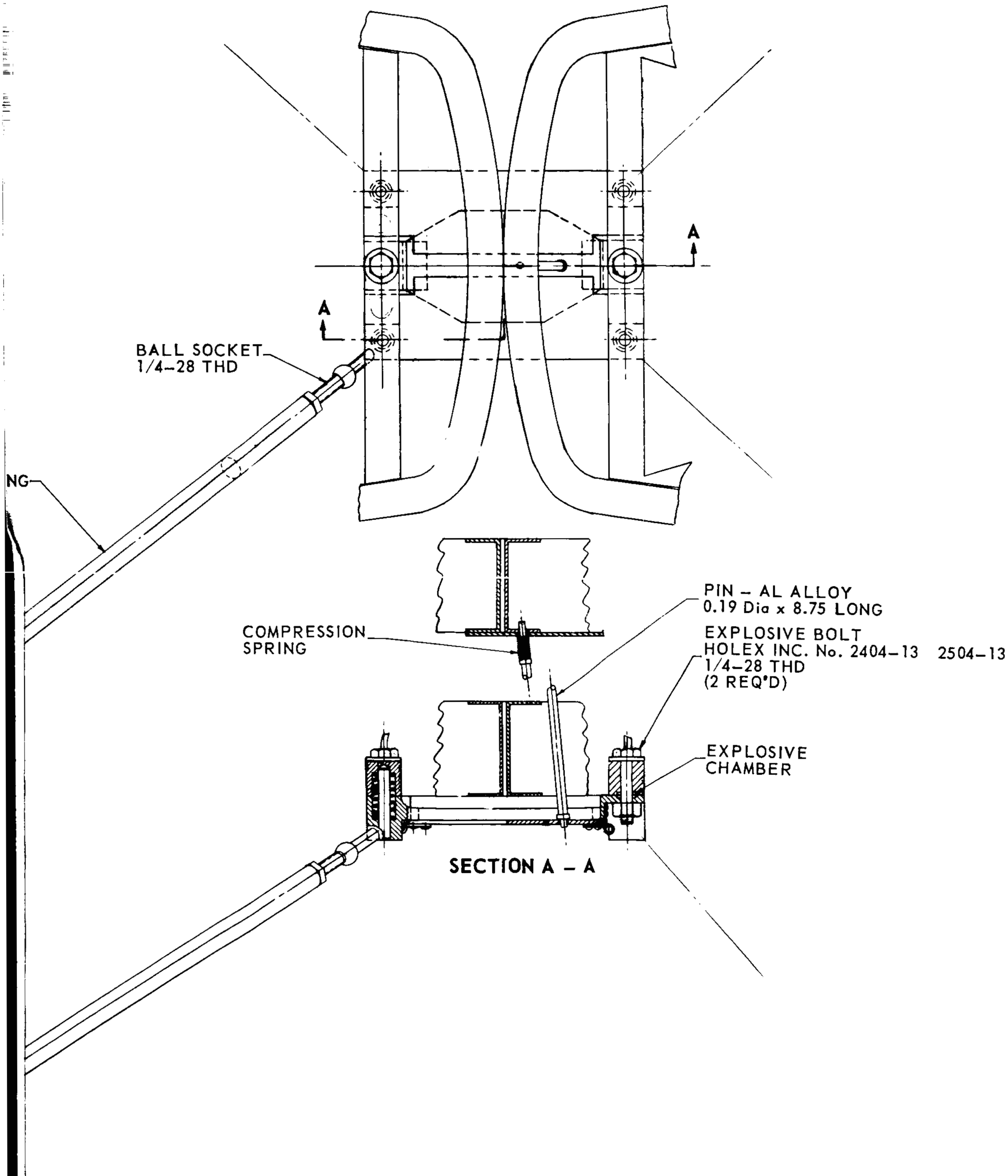


Figure 2.2-16(b) SLRV Deployment Subsystem

2

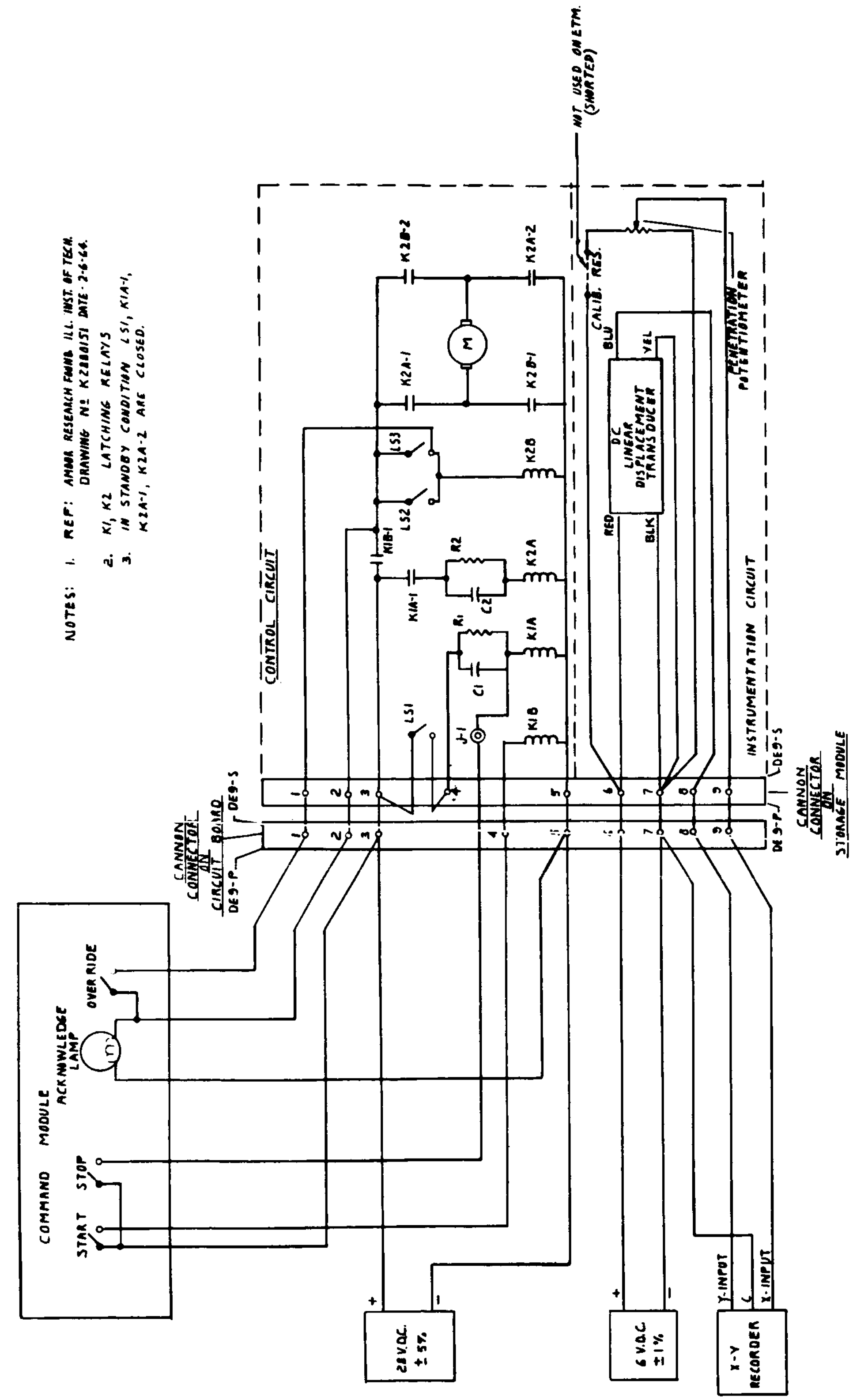
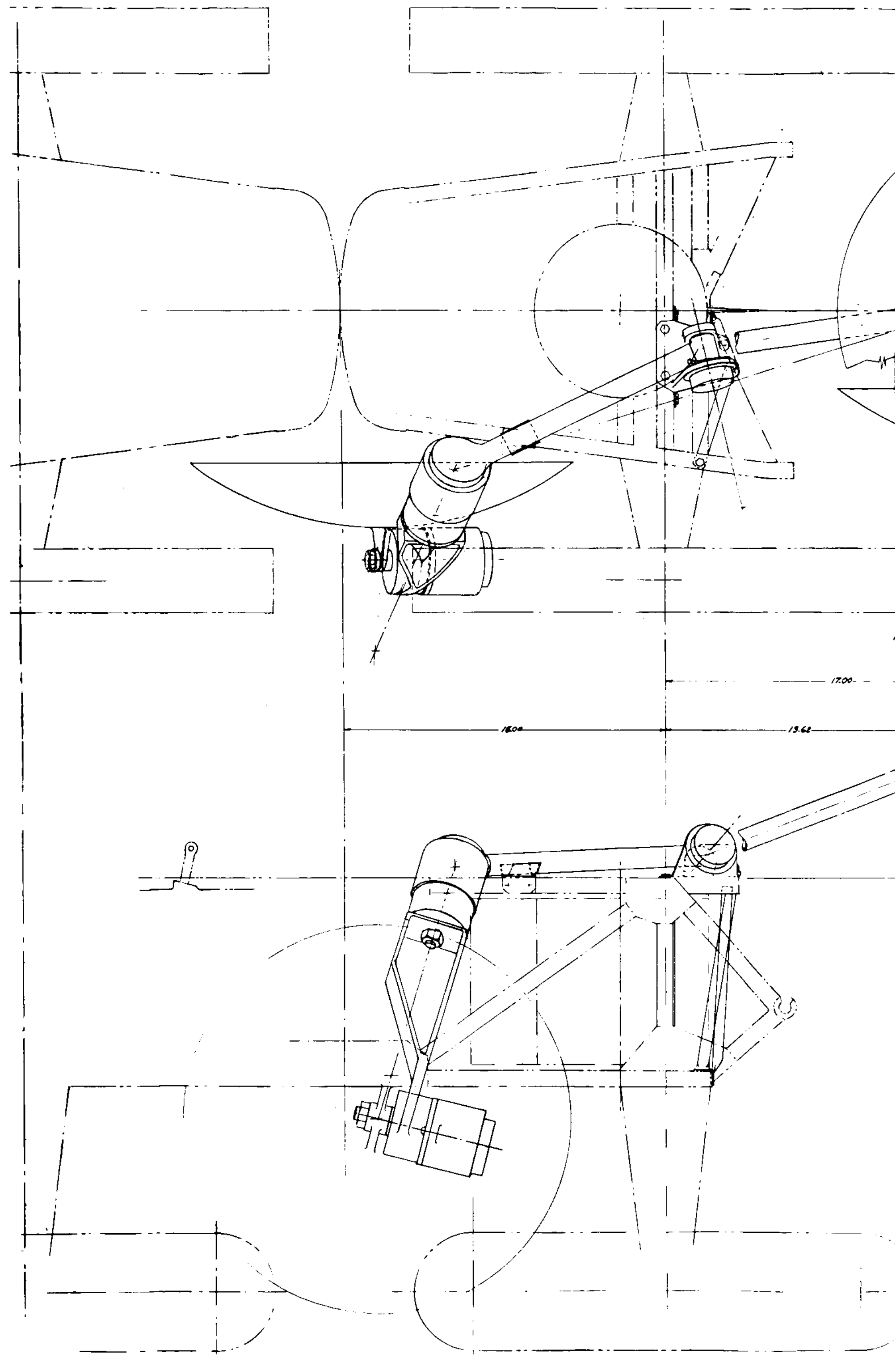


Figure 2.2-16(c) Penetrometer Circuit Diagram

2.2.10.2 Mechanical

The penetrometer package size is 5-1/2 in. wide, by 4-7/16 in. deep, by 8 in. high. The penetrometer is designed to rest on the bottom of the electronics compartment and to be fastened to the compartment top plate. A 0.825-in. diameter hole must be provided in the bottom of the compartment to permit passage of the probe tube. This hole location is approximately on the centerline of the penetrometer package and near the SLRV cg.


17.00
16.00
13.62

/

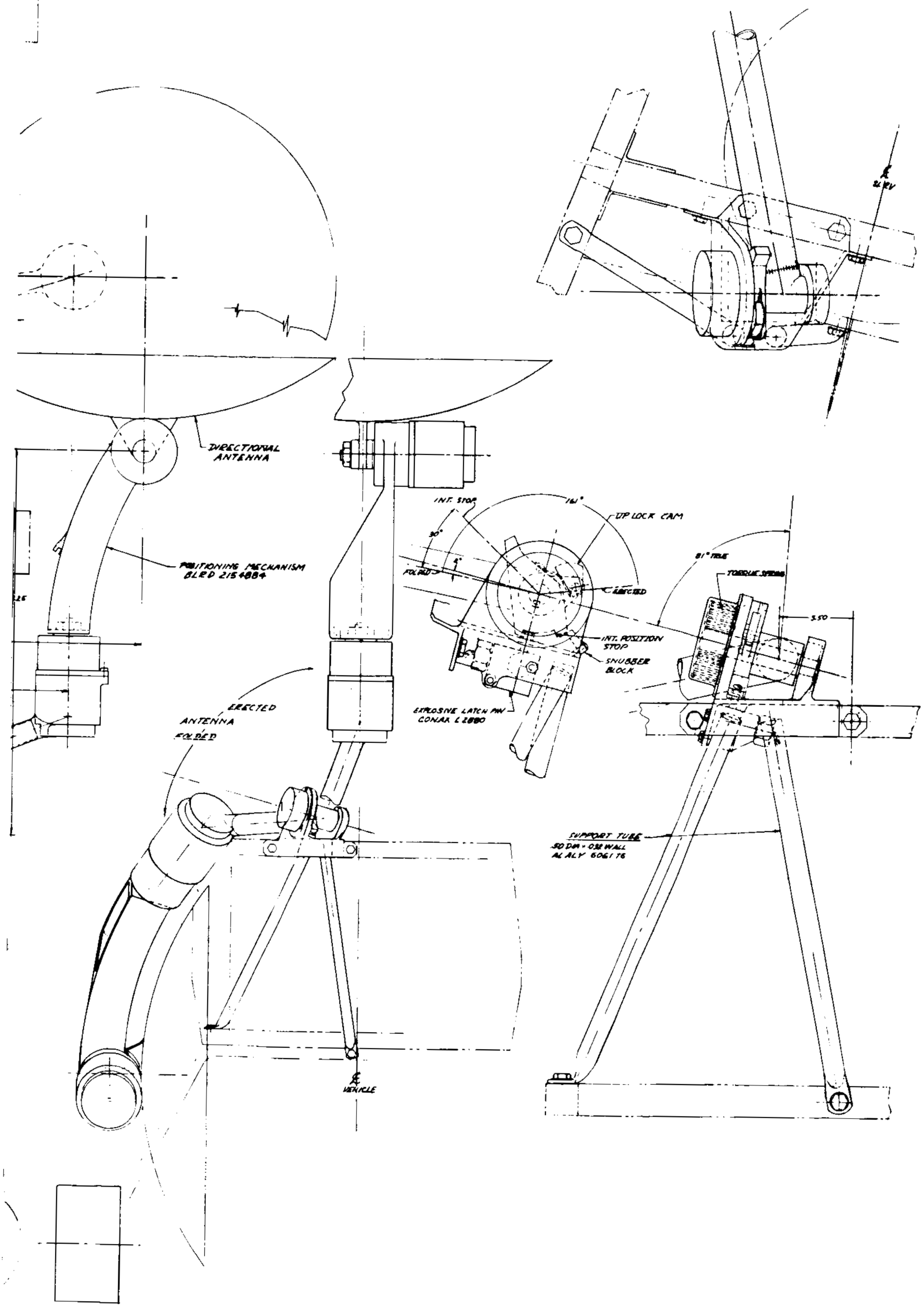


Figure 2. 2-17 Antenna Erection Assembly

2

2.2.11 Electronic Packaging Integration

Electronic packaging is covered in detail at this point, because it involves elements of many hardware subsystems. The electronic packages utilize micromodules for approximately 80% of all circuitry to minimize weight and enhance reliability. Proven components and materials are used throughout the design.

2.2.11.1 Electronic Compartment

The selection of the packaging for the SLRV electronics, principally the telecommunications and television, has been influenced by the severe weight limitations on the system. Thermal and vibration requirements were also considered, but were not as significant as the problem of weight control. The electronic circuitry was divided into three groups:

1. Digital and low power circuitry
2. Analog and high power circuitry
3. RF or microwave circuitry.

Microminiaturization of circuits in the above groups is progressing in the following hardware areas:

1. Solid state circuit modules of standard configuration such as logic gates, operational amplifiers, etc.
2. Hybrid circuitry such as special thin-film deposition to customer's specification
3. Special connectors, wiring techniques, and circuit boards
4. Encapsulating and potting compounds - thermal control surfaces and thermal insulation devices.

Using digital TV, PCM telemetry, and common modulation, much of the SLRV circuitry is composed of low power level digital components, principally "flip-flops." The logic switching rates are low, so that frequency of switching response presents no problem.

A study of existing micromodules or hybrid designs for the SLRV circuitry indicates micromodules presently available offered the following advantages:

1. Reliability test data available

2. Permit flexibility of design since circuit changes do not require major tooling changes

3. A high degree of maintainability

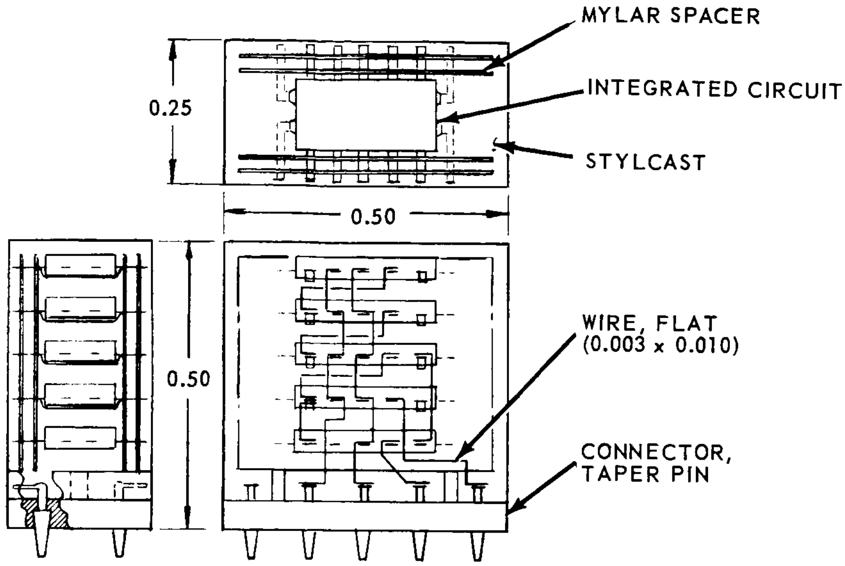
4. Less cost, development time, and testing time.

In some cases, a penalty in weight and size must be accepted when using a standard design rather than custom or hybrid designs. However, a weight analysis indicates that the penalty for SLRV is not significant. A typical module is shown in Figure 2.2-17(a). This is a Texas Instruments micrologic circuit. Five microcircuits are shown welded together and potted into a module size of 0.5 in. x 0.5 in x 0.25 in. Module leads utilize tapered pins interconnected into printed circuit boards as shown in Figure 2.2-18 (a and b). The module will then be soldered to the printed circuit board for unit assembly. The use of taper pins will permit integration testing prior to soldering. Presently, TI logic possesses the maximum "design maturity", and extensive reliability test data are available. The modules have been tested to 125° C which exceeds the thermal requirements for SLRV.

Approximately 75 to 80% of all circuits will use micromodules. However, micromodules for many applications are not now available, particularly for high frequency or power circuitry. Cordwood modules will be used for these applications. Figure 2.2-19 shows a typical cordwood module. The same module size and form factor is used and the monitoring on the circuit board remains the same.

2.2.11.2 Radio Frequency and Microwave Packaging

The telecommunication subsystem uses both VHF and UHF circuitry. Since conventional coaxial fittings and components are large and heavy, printed microwave circuit techniques for space application result in size and weight reduction and electrical performance that compares favorably with coaxial techniques. With this approach, the



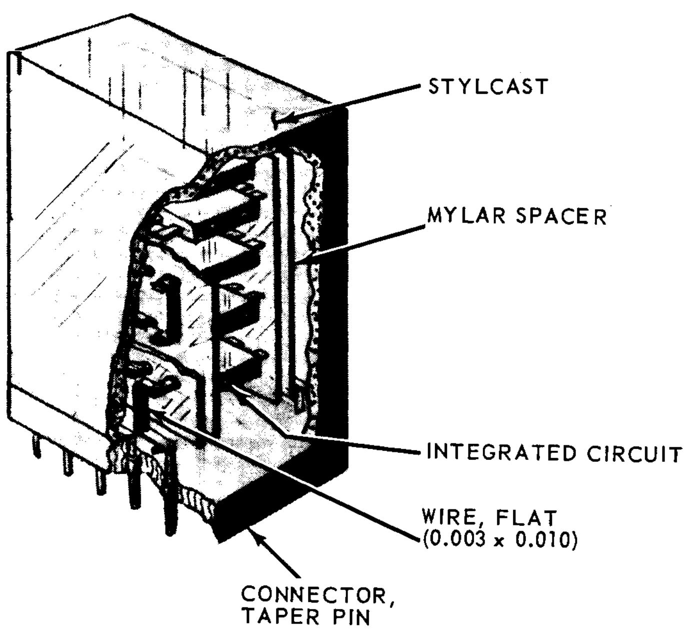


Figure 2. 2-17(a) Integrated Circuit Module

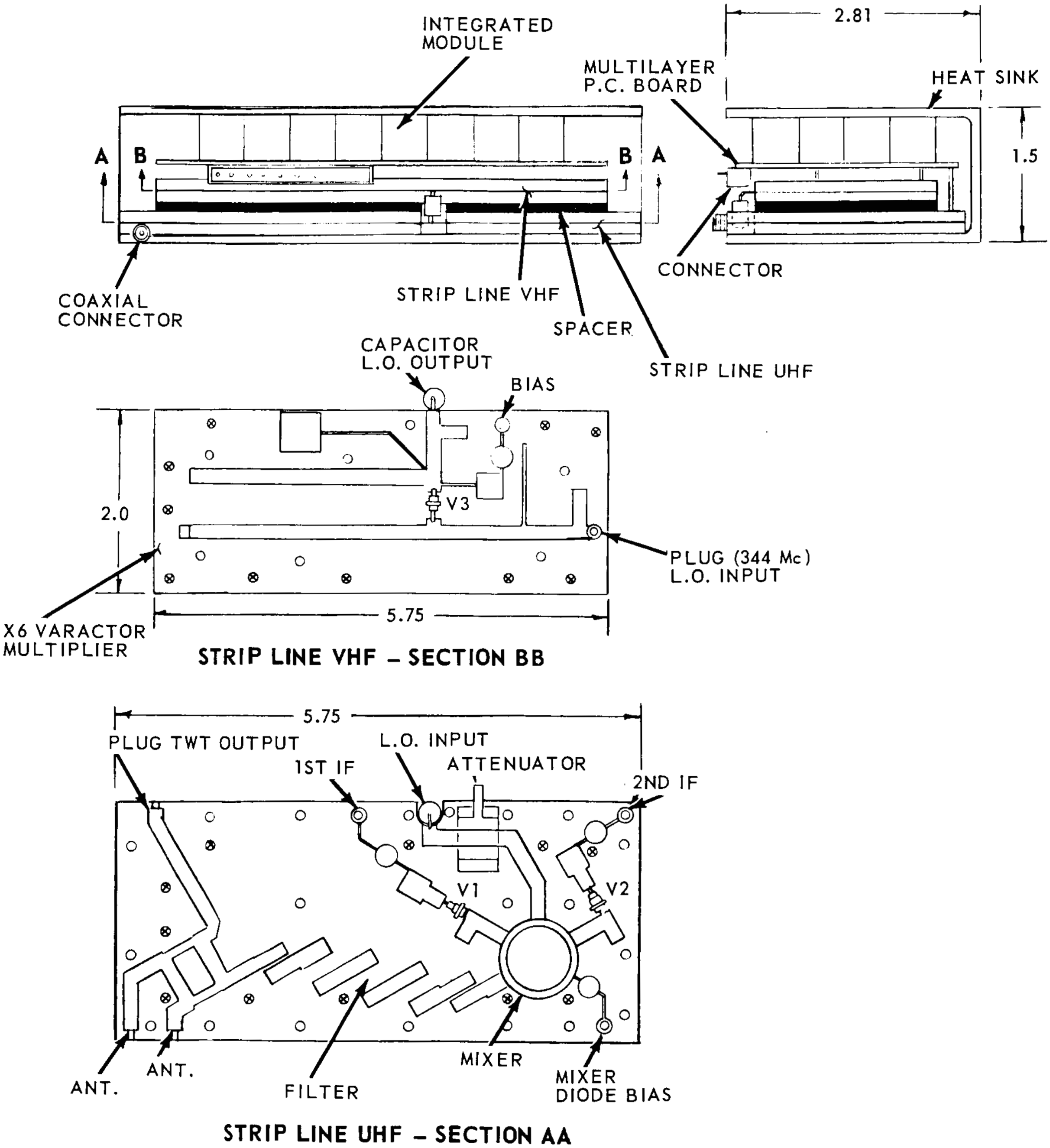


Figure 2.2-18(a) Command Receiver Assembly Arrangement

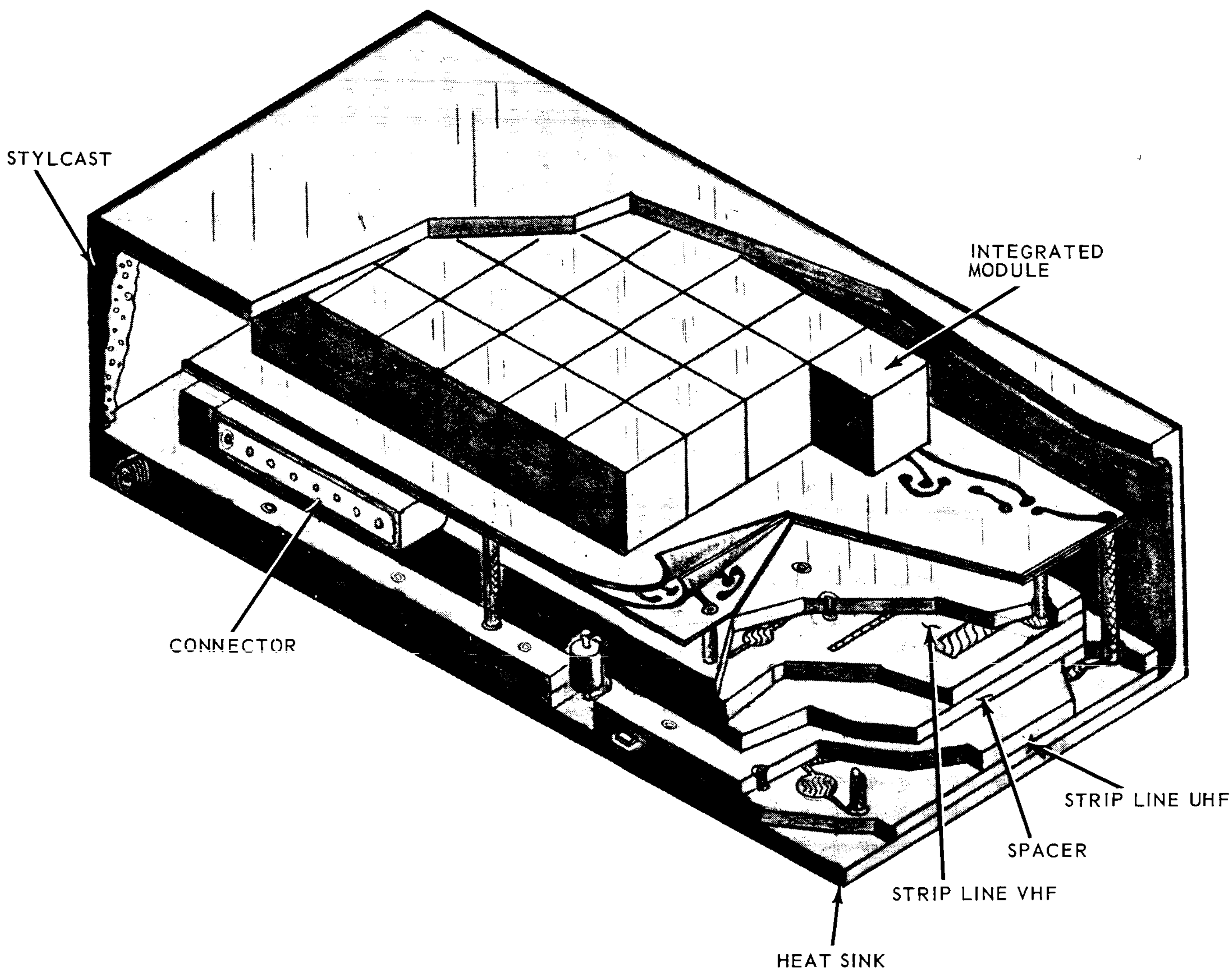
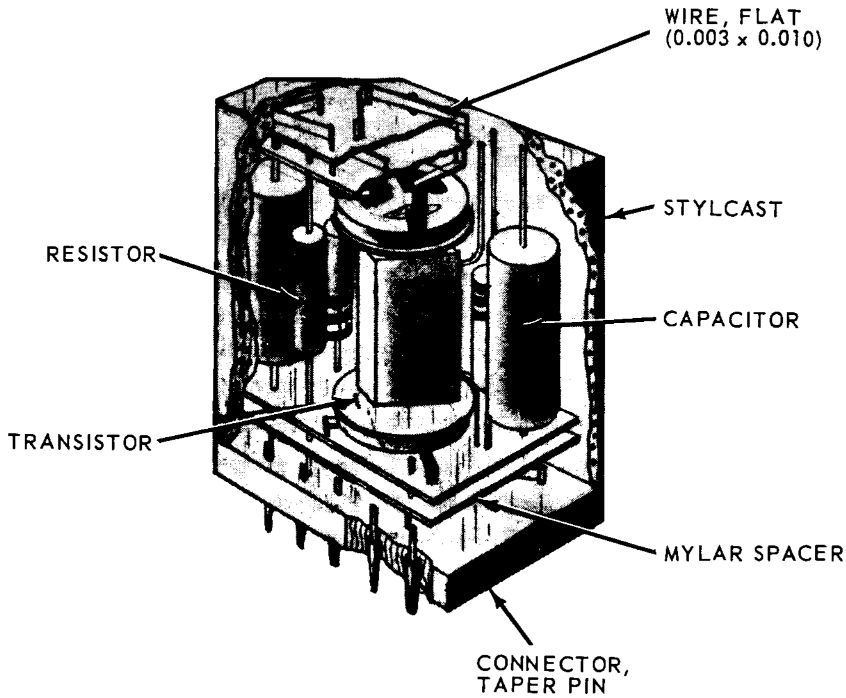


Figure 2.2-18(b) Command Receiver Assembly Cutaway View



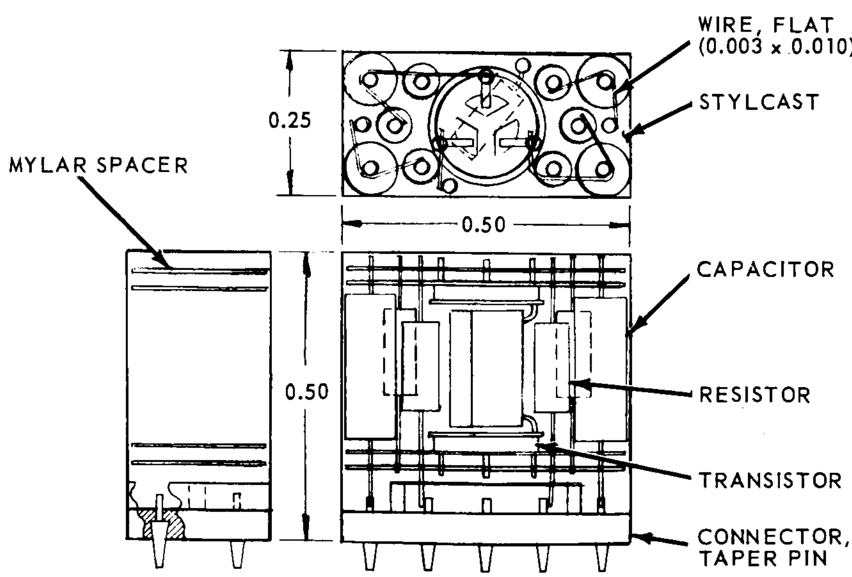
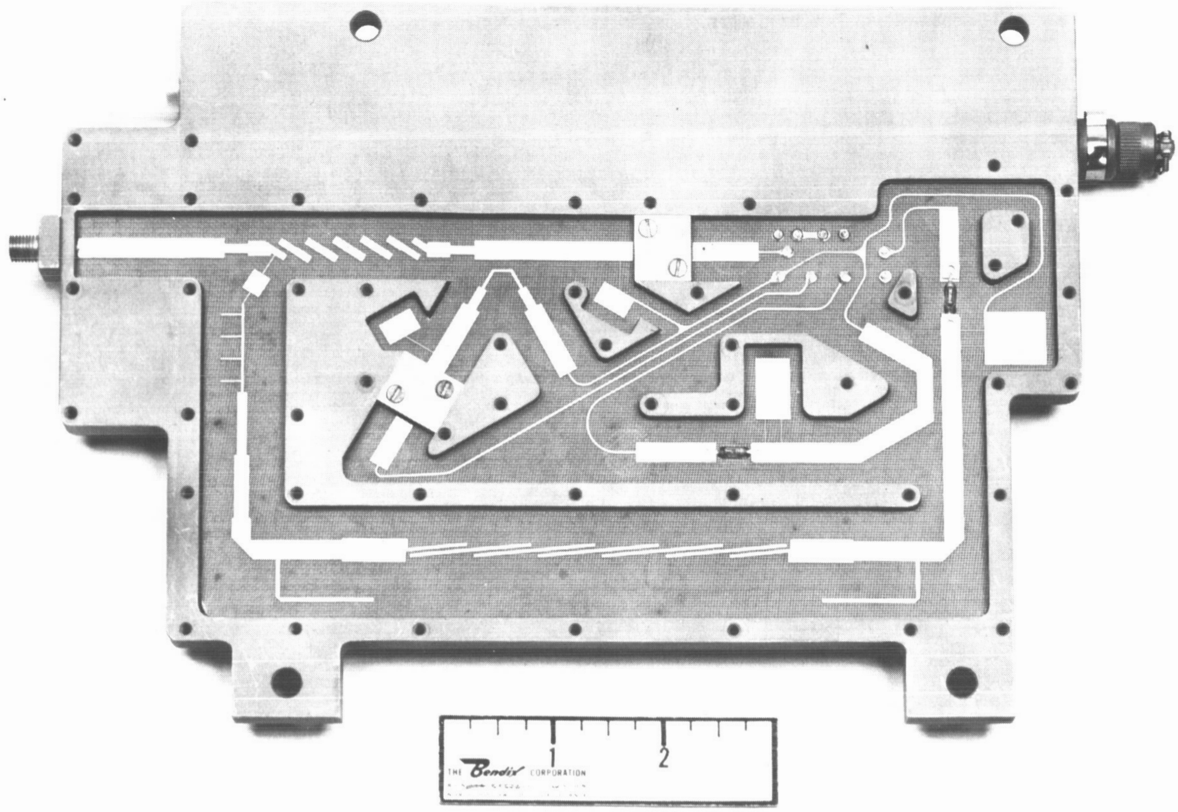


Figure 2. 2-19 Cordwood Circuit Module

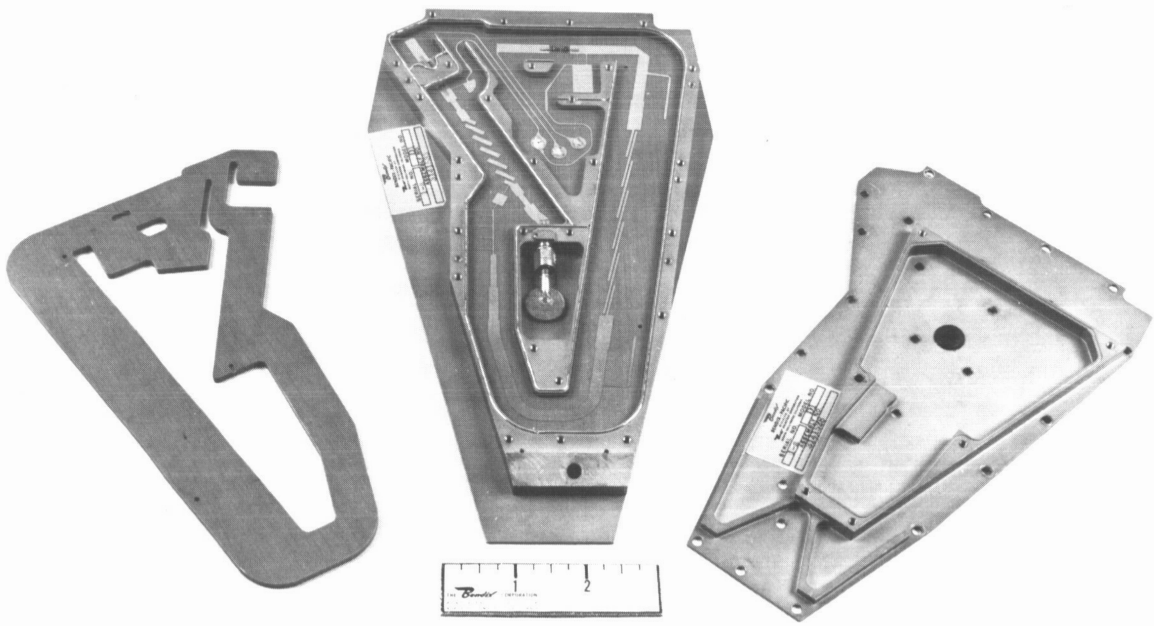
microwave printed circuit is of planar form; in many instances, an entire circuit can be deposited on a single sheet of dielectric material. The circuit performance of microwave printed circuits using "stripline" is discussed in Vol III, Book 2, Section 10. The incorporation of stripline in the command receiver is shown in Figure 2.2-18 (a and b). The receiver diplexer, filter, mixer, and local oscillator multiplier chain also employ this design technique.

Stripline uses copper-clad laminate boards. It is necessary that the boards have a high dielectric constant, low dissipation factor, and excellent homogeneous properties. Also, a minimum coefficient of thermal expansion is required, when 80 to 90% of copper from one side of the laminate is removed. Copper clad sheets are now available with thickness tolerances as close as ± 0.002 in. resulting in a uniform dielectric constant. In addition, these sheets are available with a very small loss tangent (Renoline P, for example, tan = 0.0001 at 10 kMc making the design of narrow (1%) bandpass filters possible. In the case where size reduction is a prime objective while circuit loss is relatively unimportant (the varactor multipliers driving the TWT and hybrid), materials with a wide range of dielectric constants can be purchased (Stycast manufactured by the Emerson and Cunniry Corporation, E (range) = 3 to 25).

The fabrication of the printed microwave circuit is accomplished by photographic methods. The desired layout is drawn on mylar at an enlarged scale (up to 4 to 10 times actual size). A tolerance of 0.002 in. is maintained on the master art drawing. The circuit is then transferred to Ruby Studnite, a lacquer-coated mylar base film for use with ortho-chromatic film. Utilizing blades, the circuit is cut away from the Ruby Studnite, leaving an oversized circuit negative. The circuit is then photographically reduced to actual size for etching. A light-sensitive acid resistant material is sprayed on the sheet, and the circuit image is transferred from the printing negative by exposure to an ultraviolet light source. The printed and developed sheet passes through a ferric chloride etchant that etches copper not protected by the acid resistant material. The etched circuit is then cleaned and the printed board gold plated. Gold plating provides good surface electrical conductivity and a protective finish. An example of a microwave printed circuit and the packaging techniques is shown in the photographs, Figure 2.2-20. Photograph B shows the stripline for a missile receiver. The ciruit includes diplexing, filtering, and ultra-sensitive video detection. Note the indrum sealwire



(A) For Radar Homing System



(B) For Missile Receiver

Figure 2. 2-20 Examples of Microwave Printed Circuits

protection against RFI leakage surrounding the package and various circuit cavities. Photograph A shows the printed circuit from the DPN-61 Radar Homing System. The circuit incorporates the diplexing, bandpass filtering, low pass filtering, directional coupler, micro min, video detectors, isolated DC return, and maximum environment packaging concepts.

2.2.11.3 Electronic Functional Unit Assembly

Figure 2.2-18 (a and b) show an electronic functional unit assembly. High heat dissipation elements of the unit are mounted directly on a thermal heat sink or plate. This plate, in turn, is mounted on the electronic compartment thermal plate (see Figure 2.2-21 (a and b). After assembly and checkout, each functional unit (transmitter, receiver, command processor, etc.) will be potted with an epoxy foam resulting in an integral unit not susceptible to shock and vibration.

2.2.11.4 Electronics Compartment Final Assembly

The electronics compartment consists of a thermal control surface to which all electronic functional units are mounted. A thermal box with super-insulation completely encloses the four sides and bottom of the electronics compartment. (See Figure 2.2-21 (a and b). The super-insulation material is manufactured by Union Carbide, Linde Division, and consists of multiple layers of aluminum foil. A similar technique is used on theTV subsystem described elsewhere. The insulation on the electronics compartment isolates the compartment from the rest of the SLRV structure and permits all thermal control to be accomplished by the design of the thermal plate.

Interconnection between functional units in the electronics compartment will be made by a multiple layer tape cable harness. This cable harness will be either soldered (or, perhaps welded) in place at each functional unit.

When the interconnections have been made in the electronics compartment, the compartment could be potted with a low density epoxy foam to reduce the "oil canning" effect. The use of over-all foaming is optional, depending on weight, vibration, and maintainability trade-offs during Phase II.

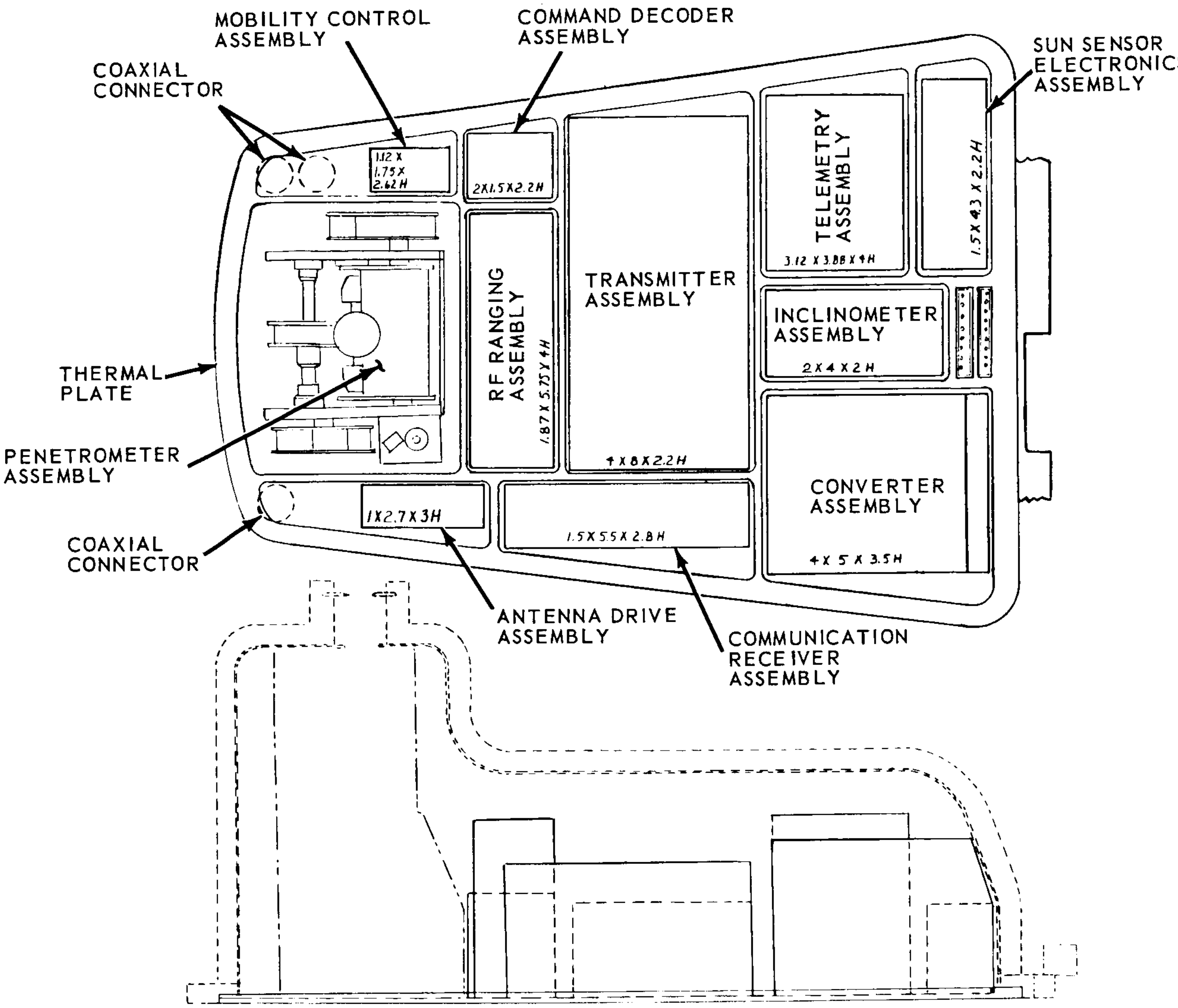


Figure 2. 2-21(a) Electronics Compartment Arrangement

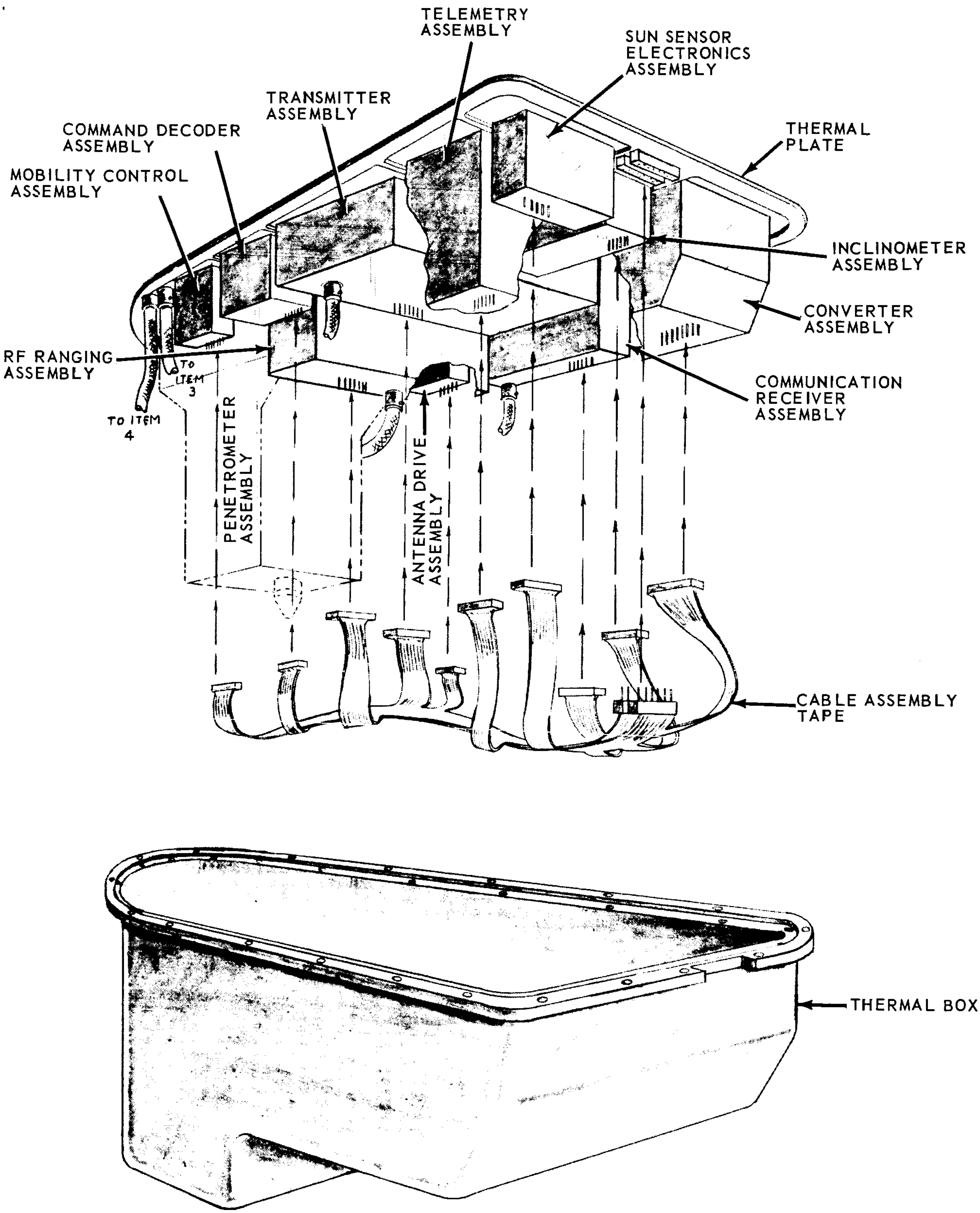


Figure 2.2-21(b) Electronics Compartment Exploded View

2.2.11.5 TV Electronics Packaging

The TV electronics package consists of four functional modules and an interconnection matrix:

1. D/A converter and deflection amplifiers

2. Encoder, sync generator, two bridge amplifiers

3. Robert's generator, H and V sweeps and controls

4. Power supply, video amp, threshold and gain controls module

5. Interconnection matrix.

Each module is completely functional and can be tested independently of the other electronics.

The technique employed in the packaging of the TV electronics is rather unique in that it incorporates the flexibility of printed circuitry with the option of soldering or welding. The electronics will be comprised almost entirely of integrated circuits from several major vendors, viz., Signetics, General Instrument, and Texas Instrument. These microelectronic packages all have a common lead breakout of 50 thousandths on center. This feature of the components permits the proposed packaging concept; i.e., the printed circuit laminate consists of a base material that has been perforated with 25 thousandths square holes over its entire surface prior to lamination. This concept is shown in Figure 2.2-22.

The printed circuit is designed around the grid structure. After the circuit is etched, a tool made to the shape of the individual microcircuits that will be employed is inserted in the grid structure which turns up the end of the etched circuit providing a 25 thousandths tab on the conductor's side of the printed board. The component leads are preformed to fit the grid structure. The components are installed and the leads soldered or welded to the 25 thousandths tab.

Circuit functions that consist of more than one etched circuit board will be joined by riser wires inserted in slots around the outer

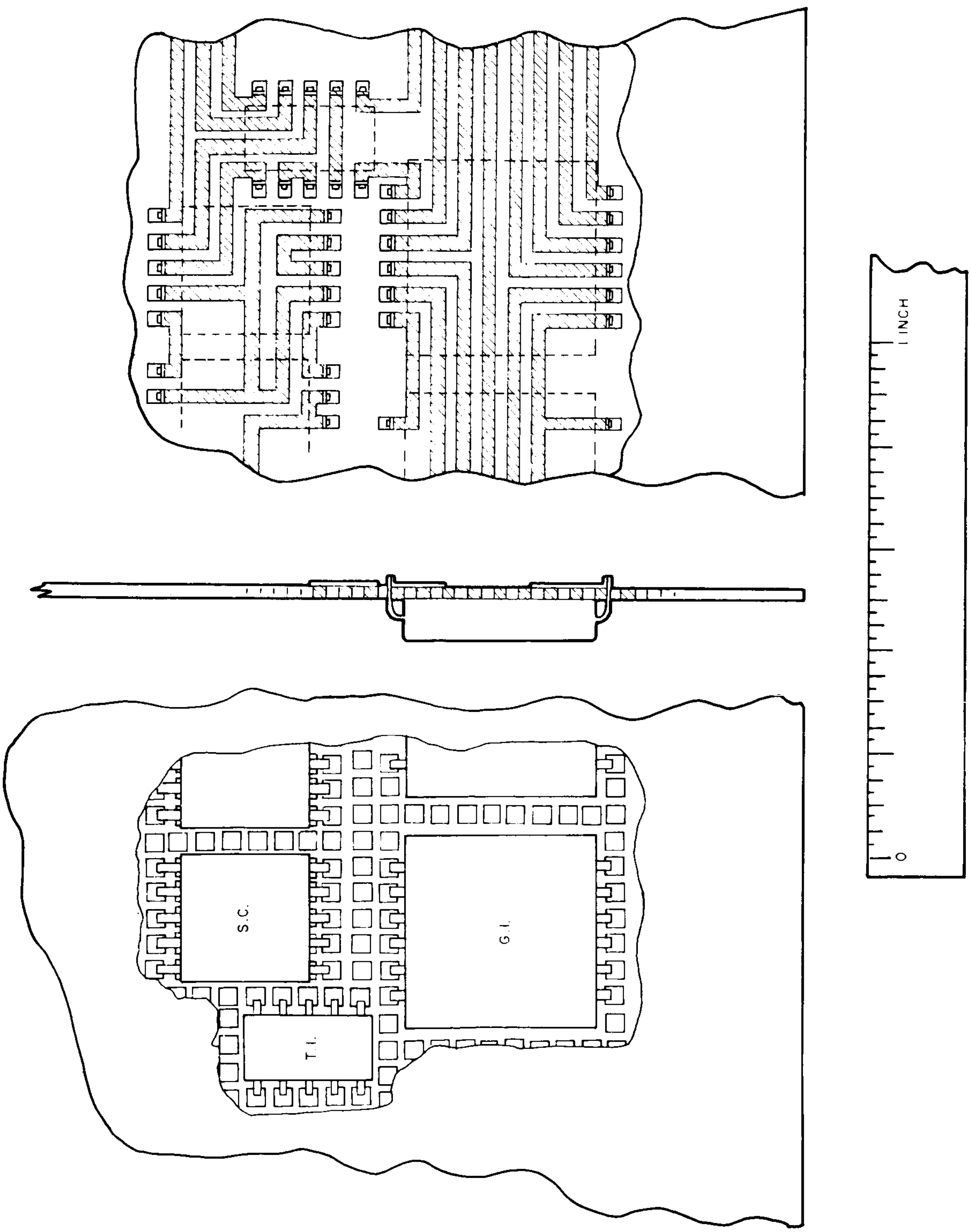


Figure 2.2-22 Second-Stage Module

periphery; this technique will provide a lightweight means of interstage interconnections and also a means of using voids caused by irregular shaped components. Layouts of the etched panels are such that protruding components will intermesh with voids on the adjacent panel. This will reduce considerably the over-all package volume.

Each functional etched panel assembly will have a flat ribbon type etched cable attached. This will provide an efficient means of performing electrical tests at module level and also prevent damage due to probing or attachment of leads during test (Figure 2.2-23). At the final integration of the electronics into the camera structure, the ribbon cables will be attached to a wiring matrix. This lightweight matrix is located at the rear of the vidicon tube providing easy access for wiring. This concept eliminates the need for connectors or interstage cabling, enhancing the over-all reliability while reducing the weight considerably.

The module size and configurations were selected so as to obtain the maximum use of voids caused by irregular shaped components in the camera, such as the optical trains, vidicon, drive and control motors, which have restrictions in placement due to their mechanical functions. This technique not only offers minimum over-all volume and minimum weight, but also provides a variable means of compensating weight and balance enhancing over-all system flexibility (Figure 2.2-24).

Module Temperature Control Considerations

Large areas of conductor foil will be retained adjacent to high heat dissipating components and will extend to the outer edge of the etched panel boards. The etched panel boards will be inserted into a slotted metal structure providing a low resistance path for heat transfer.

Moisture and Handling Considerations

After inspection, the assembled modules will be covered with a protective coating that will provide a moisture barrier, mechanical bond, and an improved thermal path. It will also prevent contamination or damage due to handling. This technique is presently being used by Raytheon on modules that must be tested under extreme conditions prior to potting. By applying several layers of this coating, subsequent potting operations can be completely eliminated providing further reduction in the over-all weight.

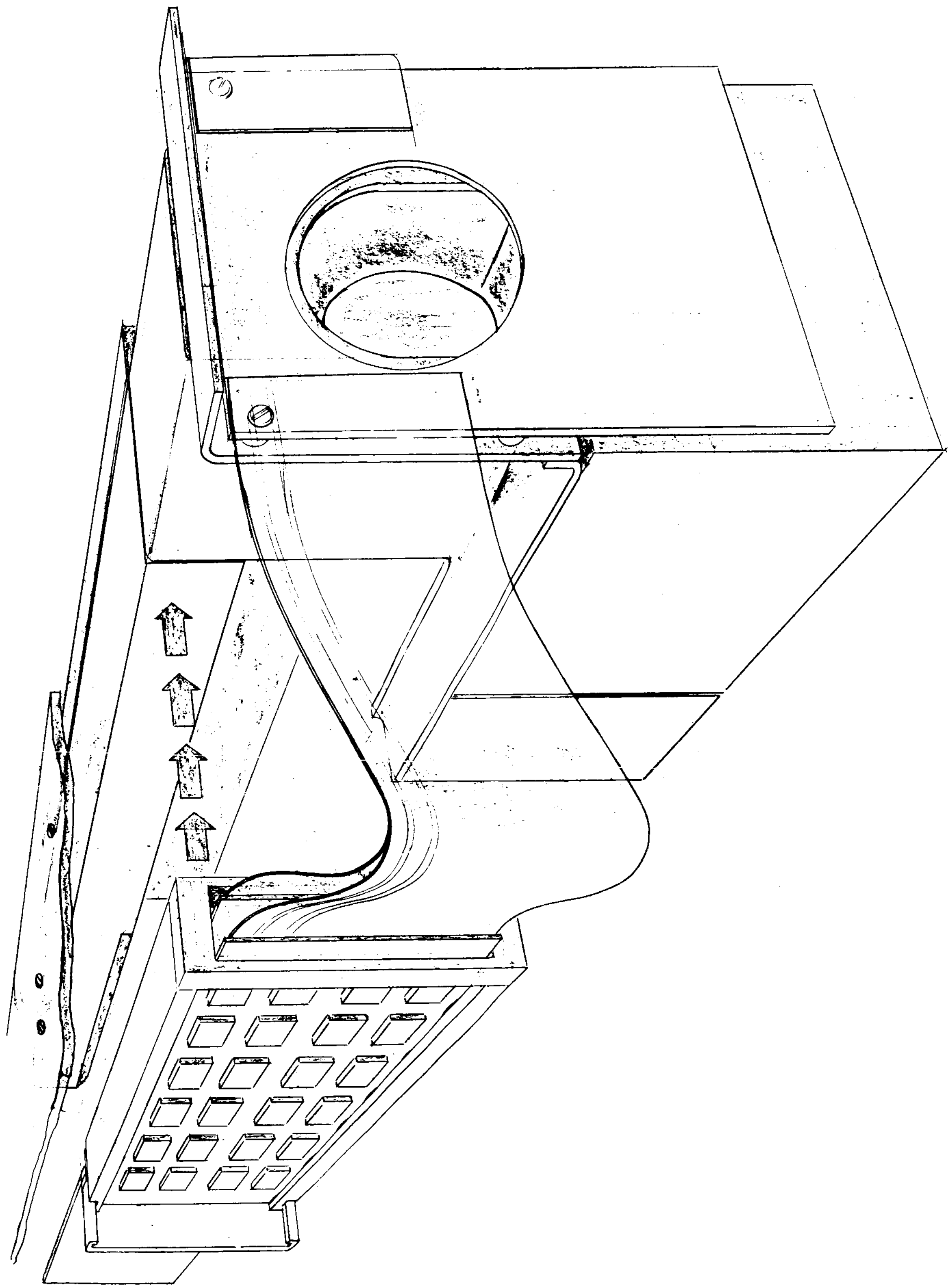


Figure 2.2-23 TV Electronics Assembly

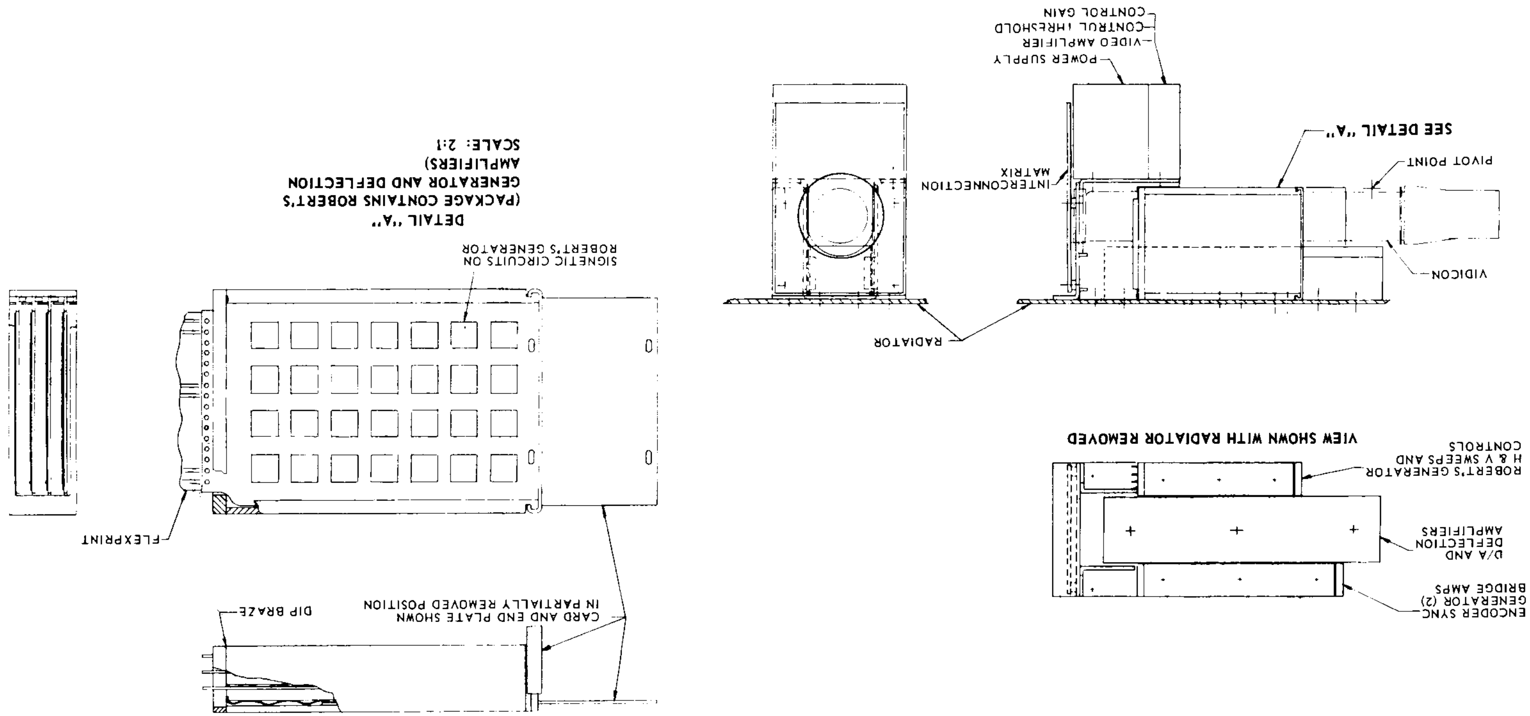


Figure 2.2-24 TV Electronics Assembly Detail

2.3 MOBILITY

2.3.1 Description

The preliminary design is a four-tracked vehicle with symmetrical floating pivot articulated body. Steering is accomplished by differential speed control of the traction motors. The tracks are individually powered at the rim.

The drive mechanism utilizes a hermetically sealed DC torque motor attached to a nutator transmission.

Subsystem preliminary design parameters and characteristics are summarized below:

1. Vehicle Arrangement:

   a. No. of tracks - 4
   b. Floating pivot articulated chassis
   c. Track base - 30 in. (center to center)
   d. Track span - 25 in. (center to center)
   e. Under carriage clearance - 10.75 in.

2. Tracks:

   Tracks consist of a prestressed metal rim, covered with a foamed silicon rubber tread, wrapped on one powered wheel and one idler.

   a. Tread width - 3 in.
   b. Powered hub diameter - 5 in.
   c. Idler hub diameter - 5 in.
   d. Length between center of idler and power hubs - 18 in.
   e. Preformed radius of rim - 3 in.
   f. Tread thickness - 1/4 in. (not including metal rim)

2.3.2 Steering and Mobility Control

Steering will be accomplished by relative rotation of the two vehicle segments about a floating pivot point and executed by means of torque developed by differential speed control of the traction motors.

Other characteristics follow:

Mode of Control - "bang-bang"

Steady-state steering conditions - (a) straight ahead
(b) hard right
(c) hard left

Vehicle nominal turn radius is 60 in. to the center of body.

A lock mechanism has been provided in order to lock the vehicle in the straight ahead, hard right, and hard left positions.

The control requirements for the SLRV traction drive mechanism (TDM) have been established as follows:

1. Each TDM shall be capable of operating up to a torque limit of 220 in.-oz. At this torque, the TDM will be automatically shut down, and will require an earth command to reactivate it.

2. The sum of the powers being consumed by the four TDMs will be limited to 8 watts. If the 8 watt total is exceeded, the vehicle will be automatically shut down and require an earth command to reactivate it.

3. Figure 2-13, Section 2, Book 2, shows operational conditions of SLRV TDMs. The control system will provide for three constant vehicle speeds which may be commanded from the earth. These speeds (referred to as N_1, N_2, N_3) are as follows:

$N_1 = 0.16$ mph

Normal operating speed of SLRV when it is on flat and relatively smooth surfaces, or up slopes on hard surfaces. Highest speed of steady state turn.

$N_2 = 0.105$ mph

Alternative operational speed for rough surface operation. Lowest speed of steady state turn.

$N_3 = 0.03$ mph

Creeper speed for climbing large obstacles.

Mobility control will consist of vehicle sensors, logic, and power control electronics to control individual traction motors and the vehicle steering lock. The input and output requirements of the mobility control subsystem are listed below:

A. Earth Command Inputs to Mobility Control

1. Forward
2. Reverse
3. Stop
4. Straight
5. Right
6. Left
7. Speed
8. Abort Track 1
9. Abort Track 2
10. Abort Track 3
11. Abort Track 4

B. Vehicle Feedback Inputs

1. Vehicle Speed
2. Straight Ahead
3. Hard Right
4. Hard Left
5. Speed - Track 1
6. Speed - Track 2
7. Speed - Track 3
8. Speed - Track 4
9. Steering Position

C. Outputs from Mobility Control to Power Transmission

1. Power - Track 1
2. Power - Track 2
3. Power - Track 3
4. Power - Track 4
5. Direction - Track 1
6. Direction - Track 2
7. Direction - Track 3
8. Direction - Track 4

D. Outputs from Mobility Control to Telemetry

1-4 - Abort Track 1, 2, 3, or 4

E. Outputs from Mobility Control to Vehicle Chassis Lock

1. Lock
2. Unlock

2. 3. 3 Traction Drive Mechanism

The traction drive mechanism includes a DC torque motor and nutator transmission. A decoupling mechanism is included to provide "free-wheeling" capability in the event of failure. Also, velocity feedback provisions yield information to the steering arrangement. Lubrication and thermal design are tailored to the lunar environment.

The overall traction mechanism shown in Figure 2. 2-16 (a and b) is comprised of the following elements:

1. A low speed, high torque DC commutated motor (Inland type-1321).

2. A nutator transmission with a gear reduction of 87/1. The flexibile member of the nutator is a bellows which also acts as a hermetic seal.

3. The structure of the traction drive contains the support bearing for the track rollers and a shield to protect this bearing and the final gear from dust or other contamination.

4. Interposed on a nonrotating member of the nutator drive is an explosive actuator which, when excited from an external source, will permanently decouple the output member of the transmission from the drive line.

5. Braking or parking capability is inherently provided by residual friction torque in the DC motor and transmission reflected through the over-all transmission ratio.

6. The hermetic chamber is pressurized with an artifical atmosphere (approximately 1 psia), and all members in this chamber are prelubricated. The pressurized gas will also function as a thermal conductor to improve heat transfer characteristics.

7. The final reduction gears and bearings are lubricated with Versilube G-300 silicone grease; they are also treated with dry film lubricants.

2.4 STRUCTURES

2.4.1 Description

The primary structure meets the objectives of reliability, high strength-to-weight ratio, and maximum structural damping. The structure is a tubular truss made primarily from 2024-T4 aluminum. Square tubing is used throughout to facilitate mounting of equipment. The tubes are joined by riveting, rather than welding, to increase the structural damping. Figures 2.2-13 show the over-all structure design.

2.4.2 Material Studies

Materials for the vehicle structure have been selected primarily on the basis of strength-to-weight ratio and fabrication ease. As stated previously, aluminum has been selected for this purpose. To avoid the possibility of cold welding in the floating pivot, a coating of aluminum oxide will be used on the circular segments against which the joint straps are resting. Teflon or other similar materials may be substituted for the aluminum oxide if this appears desirable based on cold welding studies now in progress.

2.5 DEPLOYMENT

The deployment subsystem (see Figure 2.2-16 (a and b) performs the following functions:

1. Supports the SLRV within the Surveyor during transit, within the prescribed volume and the cg location, with minimum modifications to be basic Surveyor bus.

2. Provides a thermal radiation shield to minimize radiative heat transfer between SLRV and Surveyor.

3. Provides auxiliary support for the SLRV struts and tracks; this support will be removed on command prior to deployment.

4. Deploy the SLRV on receipt of earth command.

5. Release the tiedowns of the TV camera and antennas which hold them in the stowed position during transit.

The SLRV deployment sequence after Surveyor has landed on the moon is as follows:

1. Unfasten the strut tiedown mechanism and TDA locks. The mechanism will fall free of the SLRV and Surveyor.

2. Disconnect the upper two connectors; vehicle will then be forced by springs to rotate about lower support hinge. The vehicle will disconnect completely from the Surveyor at a nominal position of 30° between the x-axis of SLRV and the local horizontal.

3. Concurrent with 2. above, the steerable antenna will be disconnected at the tiedown and then will partially erect prior to the vehicle contacting the lunar surface.

4. Disconnect the TV tiedown and whip antennas tiedowns.

5. Under certain conditions, the vehicle has to be moved a minimal distance (on the order of 1 meter) away from Surveyor before completing erection of the steerable antenna. The vehicle is now fully deployed.

2.6 FOLDING AND ERECTION MECHANISMS

Due to stowage space limitations and severe vibrational environment, it is necessary to fold and tie down such items as the TV camera and steerable antenna during flight and then release and erect them after lunar landing and SLRV deployment.

2.6.1 TV Camera Erection and Support Structure

The TV camera subsystem connects to a support mast which attaches to a spring-loaded pivot joint positioned as shown in Figure 2.2-1. The structural requirements demanded by the LRV acceleration, vibration, and thermal environments are satisfied by a camera mast of 2 3/8.in. diameter 0.005-in. gauge stainless steel tubing about which is wound a 0.025-in. thick layer of phenolic fiberglass.

During flight this assembly is folded and latched near the TV camera to a stowage fitting on the SLRV. When the explosive latch pin is withdrawn, the power spring in the pivot joint raises the camera mast with a spring rate of 12 in. -lb/rad. The spring is preloaded to an angular deflection of 65°. This stored energy will accelerate the camera mast to a velocity of 3 rad/sec at the erected position. Once the erected position is obtained, a locking mechanism prevents further motion. The 3 rad/sec angular rate does not create enough torque to upset the SLRV.

2.6.2 Steerable Antenna Erection and Support Structure

The antenna support mast must be capable of surviving the SLRV acceleration and vibration environment. This is accomplished by a 0.016-in. thick aluminum tube 1 inch in diameter wrapped with 0.030-in. thick phenolic fiberglass. The support mast is attached to a pivot at the rear of the SLRV at one end and to the housing for the antenna roll gimbal drive mechanism at the other. During transit to the moon, a tiedown lug attached near the antenna center of mass connects to the vehicle. A cradle-bracket at the top of the vehicle confines the lateral motion of the mast while stowed. Vertical motion is minimized by pre-loading the mast in the stowed position. A spring mechanism raises it to the final position in a two-step sequence. At the final position, a positive lock secures the mast.

As the SLRV leaves Surveyor, the antenna will be partially elevated and stopped near the top of the vehicle. Delaying full antenna deployment with the intermediate stop will prevent damage to the antenna which could occur if the vehicle landed with the antenna in the stowed position; it also eliminates the possibility of antenna damage due to striking Surveyor. The tiedown lug and the intermediate stop will be secured with explosive latch pins. When these latch pins are withdrawn, stored energy in the power spring (8 in. -lb/rad., preloaded 30°) will raise the antenna.

To avoid excessive momentum from overturning the vehicle, a snubber has been added to dissipate energy over the last 5° of travel.

2.7 PENETROMETER

2.7.1 Description

The penetrometer subsystem is shown schematically in Figure 2.2-16 and physically in Figure 2.7-1. The heart of the penetrometer mechanism is a preformed, longitudinally split, thin-walled tube which is flattened and rolled on a spool for storage with a minimum expenditure of weight and space. The conical penetrometer point attached to the tube carries a load cell to measure the force required to drive the probe into the lunar soil. The penetration depth is measured by recording the amount of tube which is payed out at any point in the penetration process. The penetrometer has been designed in accordance with the SLRV design requirement to measure force versus penetration to a depth of 50 cm in a soil having a gradient of 8 psi per ft.

The tube is driven by a set of friction drive rolls which are powered through a spur gear train by a small permanent magnet DC motor. The tube is stored in its flattened state by winding it on a tube storage drum which is tensioned by a negator motor drive. The payout of the tube is monitored by an angular potentiometer which senses the rotation of the tube storage drum. A worm gear is employed to reduce the angular rotation of the potentiometer to less than one turn for the entire travel of the tube (i.e., 76 cm). Cams mounted on the worm gear activate limit switches which control the extended and retracted positions of the penetrometer probe. The lead wires to the load cell are stored on a second drum also driven by a lightweight negator motor. The penetrometer operates upon command with automatic controls to limit extension, retraction, and overload. An overload limit switch mounted in the load cell reverses the motor and retracts the tube in the event that a 10-lb penetrometer load is exceeded.

2.7.2 Operation

Upon receipt of the appropriate command signal, the penetrometer mechanism will be activated, and the probe tube will be projected from the vehicle and into the soil. As the probe penetrates the soil, the load cell will sense the point of contact, and the payout potentiometer will record the depth of penetration. At a depth of 20 in., a limit signal is generated which automatically withdraws the probe until a second limit

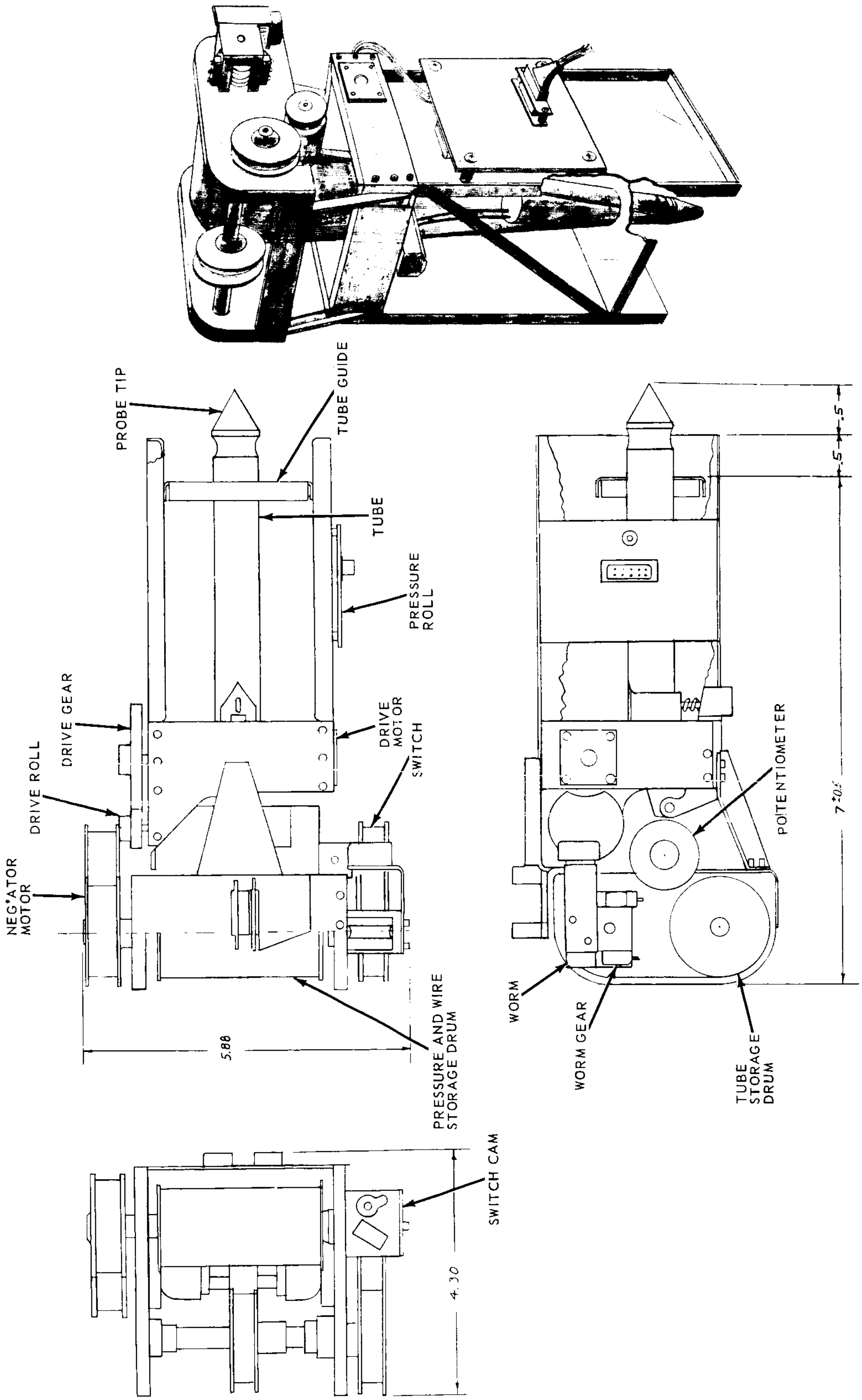


Figure 2. 7-1 Penetrometer Subsystem Configuration

signal is generated and the probe stops within the envelope dimensions of the mechanism. A safety factor in the form of a predetermined load setting is provided within the load sensing point to withdraw the probe in the event of an overload so as to prevent damage to the probe or tipping of the vehicle. The rate of penetration and retraction will be 1/2 in./sec.

2.7.3 Interface Definition

The following interfaces exist between the penetrometer subsystem and the SLRV or the ground control station.

2.7.3.1 Command Signal

The command signal required to initiate a single phase of operation of the penetrometer will be a 28-volt positive-going pulse with a time duration of 10 milliseconds or greater. Two other command pulses will be necessary; one to provide an override signal to stop and retract the probe during the operation cycle, and another to initiate the explosive charge destroying the tube in case of hang-up.

2.7.3.2 Voltage

The penetrometer mechanism requires two voltage supplies: one 28-volt supply for the DC motor, and one regulated 6-volt supply for the instrumentation and control circuits.

2.7.3.3 Mechanical

The penetrometer package size is 5-1/2 in. wide by 4-7/16 in. deep by 8 in. high. The penetrometer is designed to rest on the bottom of the electronics compartment and be fastened to the top plate of the compartment. A 0.825-in. diameter hole is provided in the bottom of the compartment to permit passage of the probe tube. This hole location is approximately on the centerline of the penetrometer package and near the center of gravity of the vehicle.

2.7.3.4 Data Transmission

The load and displacement signals generated by the penetrometer are sampled at a rate of 21 readings per second for each analog signal. The required accuracy for data transmission is 1/2 of 1 percent for both analog signals.

2.7.4 Physical Characteristics and Constraints

The physical characteristics of the penetrometer subsystem shall be as follows:

2.7.4.1 Size

The maximum envelope dimensions for the penetrometer and related electronic equipment shall be 5-1/2 in. x 4-7/16 in. x 8 in.

2.7.4.2 Weight

The penetrometer weight as a design goal shall not exceed 2.75 lb.

2.7.4.3 Power

The power requirements of the mechanism to fulfill the soil measurement function shall not exceed 5 to 6 watts. Exact power levels are difficult to predict accurately since they depend on frictional effects. The power required for penetration into the soil is approximately 0.6 watt. The remainder of the power is associated with frictional losses.

2.7.4.4 Vehicle Constraints

The SLRV penetrometer will tolerate side loads up to 2 lb in the fully extended condition. To avoid damage to the penetrometer, the roving vehicle must be restricted to slopes which will not permit a 2-lb side load to develop (approximately) 8^{o} on a zero friction surface).

2.8 NAVIGATION

The navigation subsystem is comprised of an inclinometer, a solar aspect, an RF ranging unit, and an odometer. The television camera is also used for navigation purposes but is not an explicit portion of the navigation subsystem.

2.8.1 Inclinometer

The inclinometer is used to sense deviations from the local vertical of the SLRV pitch and roll axes. This information is used for transformation of the solar aspect sensor measurements to the local reference plane and to provide surface slope measurements. An accuracy of 10 arc-minutes on the lunar surface is required for each body axis measurement in both static and dynamic conditions. The inclinometer is comprised of two linear accelerometers mounted about the vehicle pitch and roll axes. Each accelerometer is an open-loop device incorporating a floated pendulous gimbal with instrument ball bearing suspension and wide range microsyn-type pickoff.

Each inclinometer is comprised of two accelerometers and associated electronics.

The active range of each accelerometer is $\pm 30^{\circ}$ on the lunar surface. A measurement accuracy of 10 arc-minutes over a $\pm 15^{\circ}$ range is provided. The accelerometer natural frequency has been selected at one cps, and the anticipated damping is 0.7 of the critical value. Each inclinometer output signal has a range of 0 to 5 VDC corresponding to the $\pm 30^{\circ}$ range. The complete two-axis unit electronics occupy 2 cubic inches and weigh 20 grams. The total inclinometer weight is 1.0 lb; total power input is 1.76 watts at 28 VDC.

2.8.2 Solar Aspect Sensor

The solar aspect sensor is the primary sensor for the vehicle azimuth. The digital device which has been selected is comprised of four sensing heads and associated electronics. Each sensing head employs dual reticle detection elements to encode the solar azimuth and elevation lines into eight levels, providing $1/2^{\circ}$ resolution in solar azimuth and elevation. At binary code crossings, an accuracy of $\pm 1/4^{\circ}$ is achieved. The four sensing heads are arranged such that complete coverage of the hemisphere is provided. Data are presented in parallel form continuously in two 8-bit buffer registers. Each detector head incorporates an identification cell for coding of the solar measurements to a particular head. Total sun sensor weight is approximately 2-1/4 lb. The total power required is 295 milliwatts.

2.8.3 RF Ranging Unit

An RF ranging unit employing an active transponder on the Surveyor spacecraft is used to provide continuous range information between SLRV and Surveyor. The ranging function is performed using interferometery. Two CW low frequency signals of 80 kc and 2 Mc are used to frequency modulate a VHF carrier at 145 Mc. A vertical whip with azimuthal pattern symmetry is used as the SLRV radiator. The signal is received at the Surveyor with another whip antenna and is translated to 125 Mc. The 125-Mc signal is retransmitted to the SLRV through the Surveyor whip with the aid of a diplexer. The 125-Mc signal received at the SLRV is separated from the transmitted signal by another diplexer and demodulated by a limiting IF strip and discriminator, producing 80-kc and 2-Mc baseband outputs. Phase comparison of these two signals with appropriate crystal references produce an output proportional to range. Phase detection accuracy is sufficient to provide range measurements to within ± 1 meter.

2.8.4 Odometer

The odometer is basically a "fifth wheel" with a 5.75-in. diameter and 1.0-in. width. It is attached to the outside center of one of the four traction drives by means of a leaf spring. The leaf spring is used to apply a slight pressure on the odometer to ensure contact with a rough surface. Travelled distance is measured by counting revolutions of the odometer wheel. This is accomplished with a reed switch which pulses 18 times per revolution or every 2.55 cm of vehicle travel. These pulses are used to step a shift register which in turn is interrogated 6 times/sec by the telemetry subsystem. The register may be reset by command from the ground controller.

2.9 CONTROL AND DISPLAY

The SLRV is remotely controlled from the ground by a vehicle operator. The operator is located at the ground command/display console in a real-time closed-loop manner. The vehicle operates in a discontinuous (STOP-GO) fashion. At any particular stopping point, one or more video pictures of the immediate foregound are taken for the operator's benefit. Interpreting these pictures with respect to his overall short term and long term objectives, the operator selects a tentative path for the next travel step of 3 meters or less. Auxiliary symbols superimposed on the TV picture indicate the relative geometry of the picture, vehicle orientation, and TV camera pointing for the operator's benefit.

A prediction technique is used during vehicle motion to minimize dynamic considerations of the steering control problem. The prediction is accomplished by computing in fast time and displaying in real-time the predicted response of the vehicle to the current instantaneous command stick setting. The prediction will use an initial condition parameter set derived from the processed navigation information and recent commands sent to the vehicle. The prediction is updated at a rate of two times per second, corresponding to the command input rate. The vehicle position is predicated and displayed for a total of three meters ahead of the instantaneous vehicle position.

Figure 2.9-1 illustrates the complete display. The past position of the vehicle is shown as two lines, behind the instantaneous present position of the vehicle, which is shown by an appropriate rectangle. The predicted position of the display, using the current vehicle steering commands, is shown on the remainder of the display for a total length of 3 meters beyond the present position. By aligning the predicted vehicle track path with the overall desired path, the vehicle can be carefully controlled along the desired path.

In addition to normal vehicle operation, capability for alternate modes of vehicle operations will be provided, permitting irregular turns and slow speed operation for obstacle crossing and climbing. These alternate modes of operation will be used in situations wherein normal vehicle operation is either impossible or difficult. Typical examples might be driving the vehicle backwards, crossing a crevice, and climbing a large obstacle. Operation in alternate modes is expected to constitute only a minor percentage of the total operation.

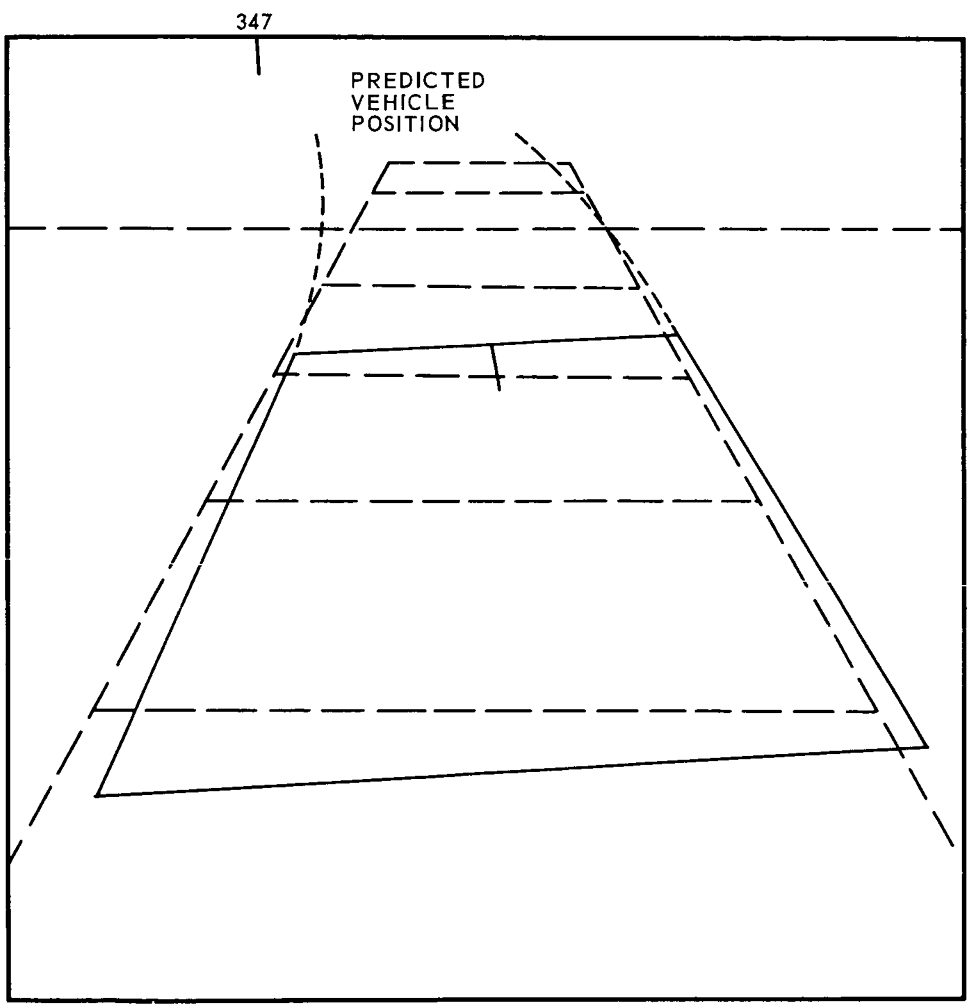


Figure 2.9-1 Driving Display Path Description

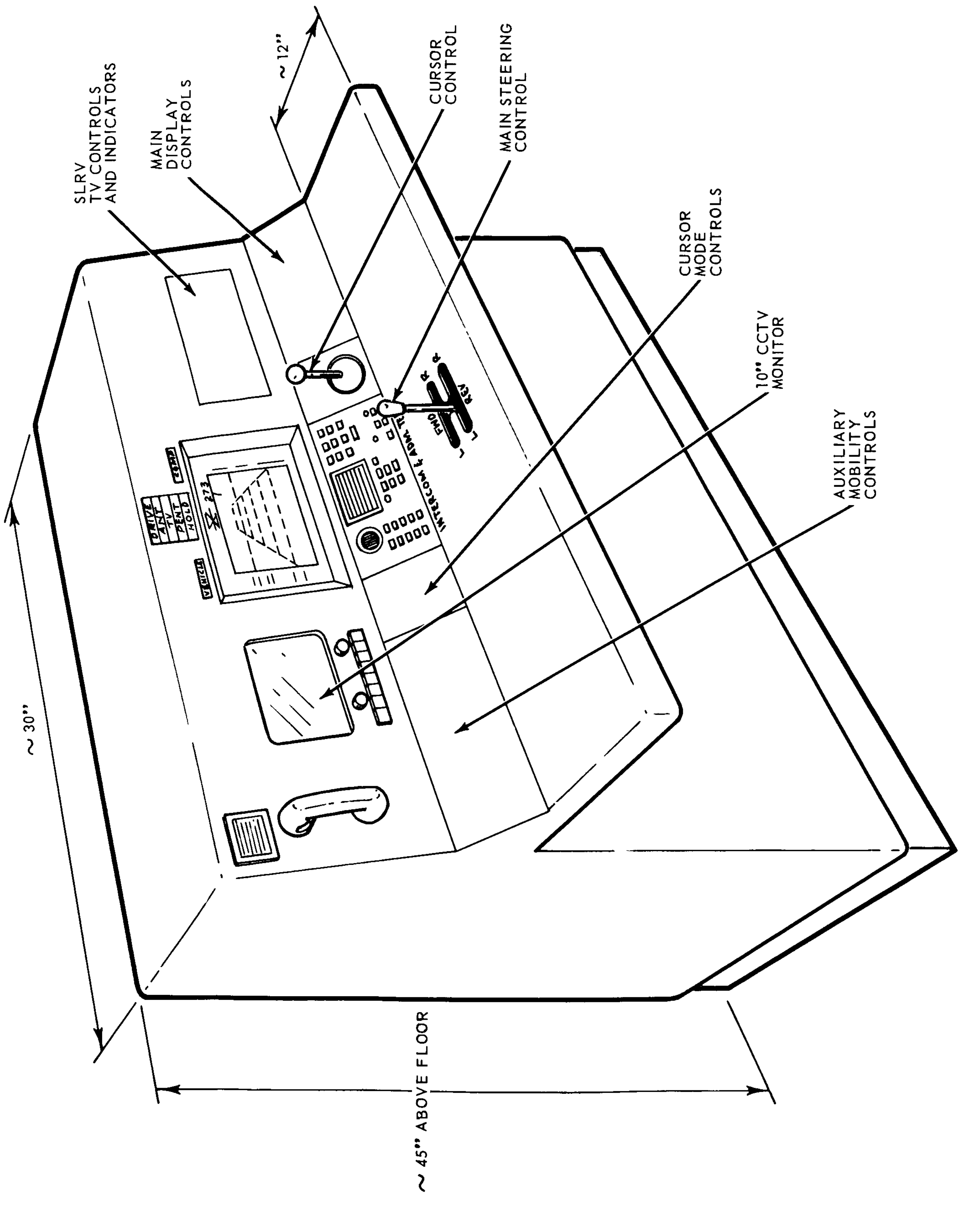


Figure 2. 9-2 Vehicle Operator's Control Console

Other display information and control functions will be available to the vehicle operator, in addition to that required for steering control. These are described briefly here and in greater detail in Section 13, Book 2. Figure 2.9-2 illustrates the operator's control and display console. The operational mode indicators display the mission status. A warning indicator provides a vehicle malfunction indication. Vehicle body inclinations are provided to indicate dangerous stability conditions. A cursor, cursor mode controls, and display controls allow operator communications with the computer and display. A closed-circuit TV monitor is available for information control purposes. Controls for pointing the vehicle TV camera for driving purposes are provided. The operator generates steering commands for the vehicle through use of the steering command stick. Manual vehicle mobility controls are also at the disposal of the operator.

2.10 TELECOMMUNICATION DESCRIPTION

The hardware items of the SLRV telecommunication subsystem are:

1. Data Handling

   Command Decoder

   Telemetry Processor

2. Data Link Transmitter

3. Command Receiver

4. Antennas

   Omnidirectional

   Directional

2.10.1 Data Handling

The major units of data handling equipment are the command decoder and the telemetry processor. The block diagram of the command decoder is shown in Figure 2.10-1.

Three subsystem decoders are used, the TV decoder, the communications and penetrometer decoder, and the mobility decoder. Each of the

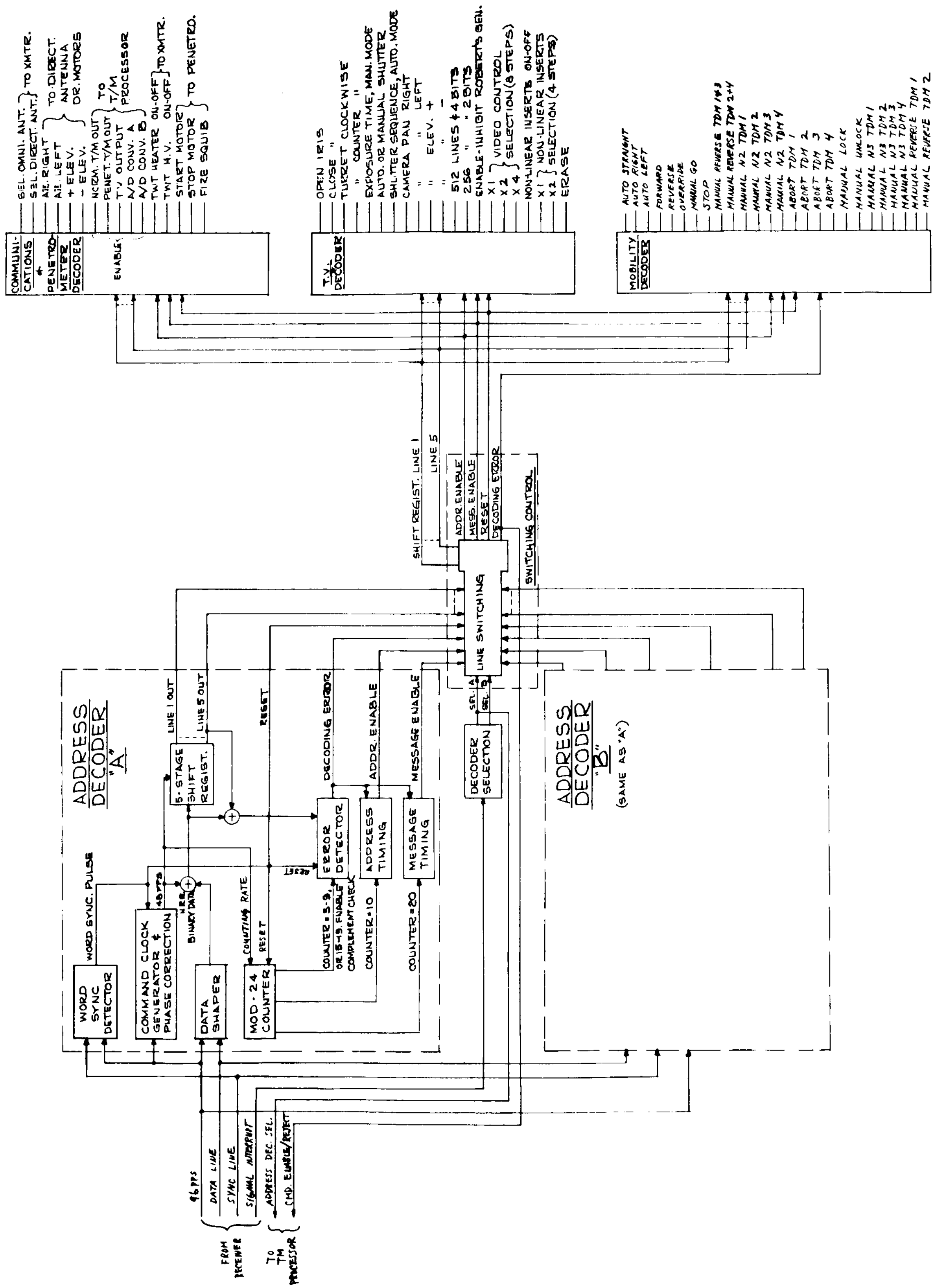


Figure 2.10-1 Command Decoder Block Diagram

subsystem decoders is capable of decoding 32 commands giving overall subsystem capability of 96 commands.

Only 71 commands are required for operation of SLRV. The distribution of the command requirements among the subsystem is given below:

TV - 21 commands

Communication - 15 commands

Penetrometer - 3 commands

Mobility - 32 commands

Two redundant address decoders are provided to enhance reliability. They are switched whenever iterrruption of the command transmission occurs and their status is monitored via telemetry. The command work format is shown in Figure 2.10-2. The commands are transmitted at 48 bits per second rate, thus providing one command every 0.5 second. The transmission is continuous with fill-in bits transmitted between commands. Complement of address and the command allows a high degree of error detection. When errors are detected, the command decoder is inhibited and the fact telemetered to earth.

The command decoder is constructed using 248 TI, series 51 integrated circuits, and has the following parameters:

Size: 2" x 2-1/4" x 1-1/2"

Weight: 0.25 lb

Power: 1.1 watts at 3 volts.

The telemetry processor block diagram is shown in Figure 2.10-3. Four modes of operation are specified:

1. Normal TV mode at 122,880 bits/sec
2. Degraded TV mode at 960 bits/sec
3. Telemetry mode at 960 bits/sec
4. Penetrometer mode at 960 bits/sec.

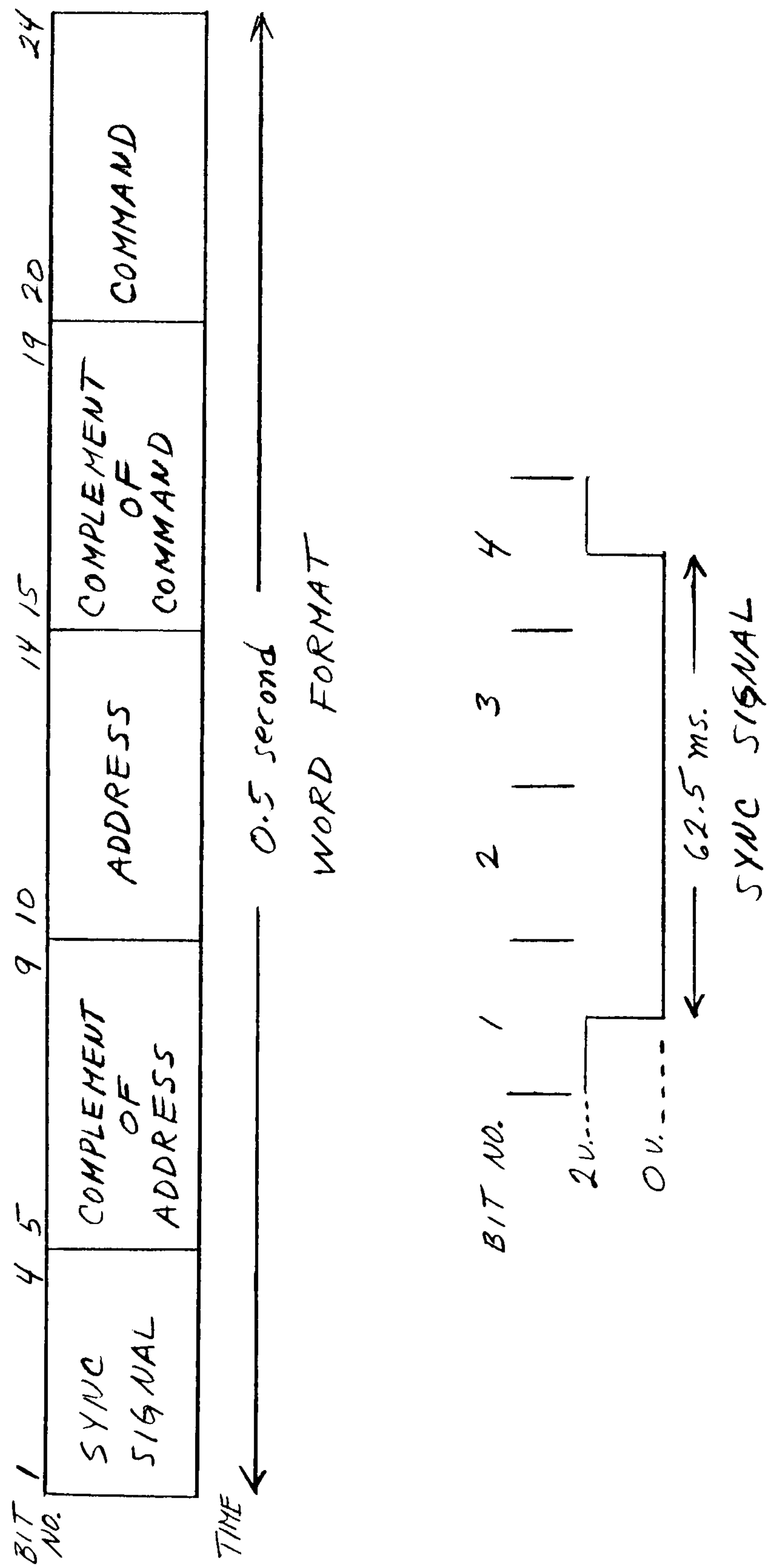


Figure 2.10-2 Command Format

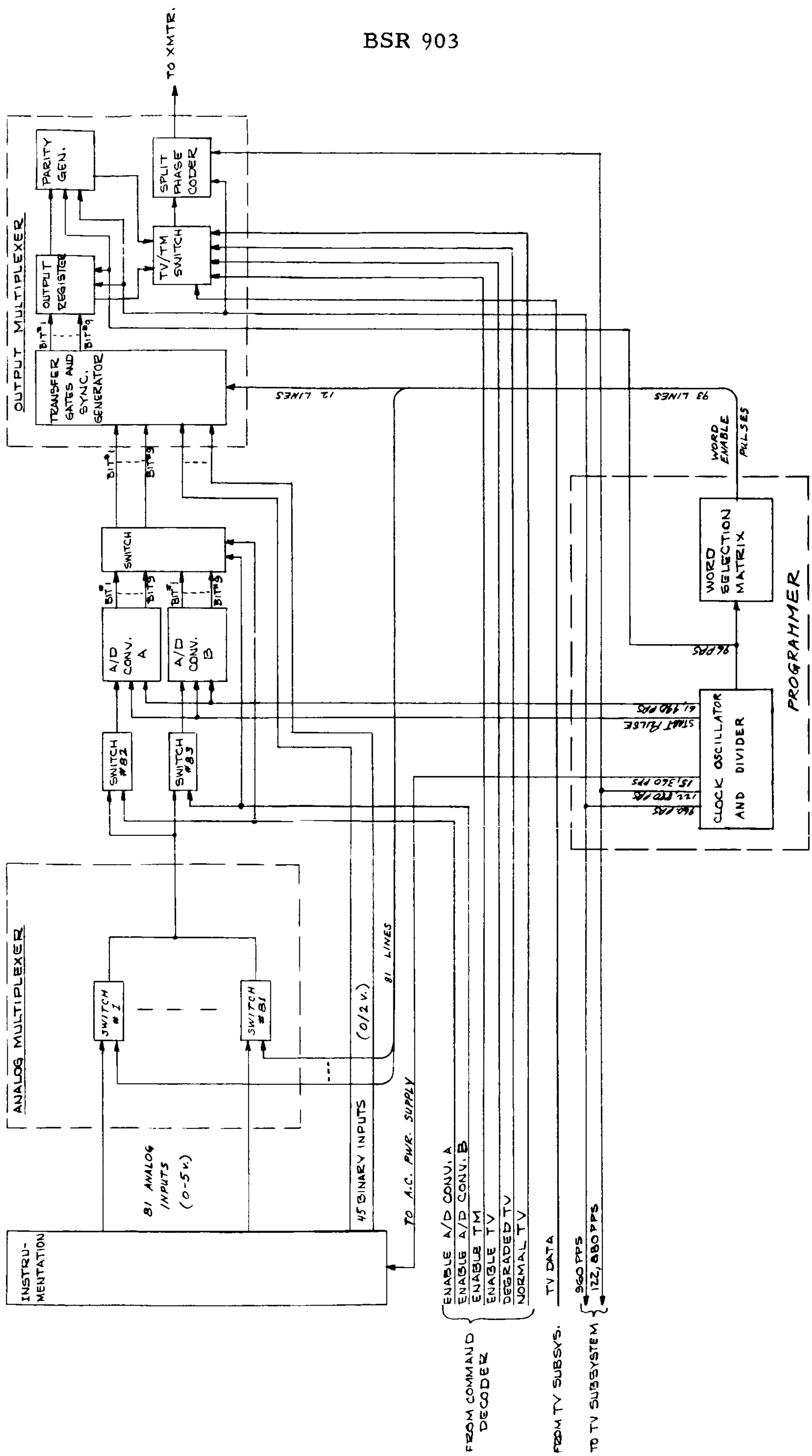


Figure 2.10-3 Telemetry Processor Block Diagram

The television provides a serial data input to the telemetry processor. In normal telemetry mode, the following sampling is provided:

65 high level points

12 low level points

45 binary points

In the penetrometer mode 7 high level points are sampled. Work format and frame format for various modes are given in Figure 2. 10-4.

Two redundant A/D converters are provided for reliability. The converters are of a ramp type capable of 9 bit encoding, in 8. 3 milliseconds. Triplicated majority logic is used in dividing clock chains and counters.

The telemetry processor uses TI, series 51 integrated circuits and National Semiconductor INCH (INtegrated CHopper) circuits for switching, and has the following parameters:

Size: 4" x 3. 875" x 3. 125"

Weight: 2. 5 lb

Power: 3 watts.

2. 10.2 Data Link Transmitter

The block diagram of the data transmitter is given in Figure 2.10-5. It operates in S-Band. The transmitter is completely solid state except for the travelling wave tube. A reference oscillator signal is derived from the receiver. The receiver oscillator is a crystal controlled VCO and will lock on to the DSIF transmitter, thus providing a transponder mode of operation for the carrier. The constant ratio (221/240) between received and transmitted signal simplifies the acquisition procedure. The input reference signal of 19 Mc and is provided at 1 mw power level. A transistorized X5 multiplier will convert the reference signal to 95 Mc, a power loss of 2 db will occur. The varactor X3 stage is driven with 3 mw. A conversion efficiency of -5 db is realized. The modulator is a single-stage transistor amplifier, whose phase response is controlled by a biased varactor. A

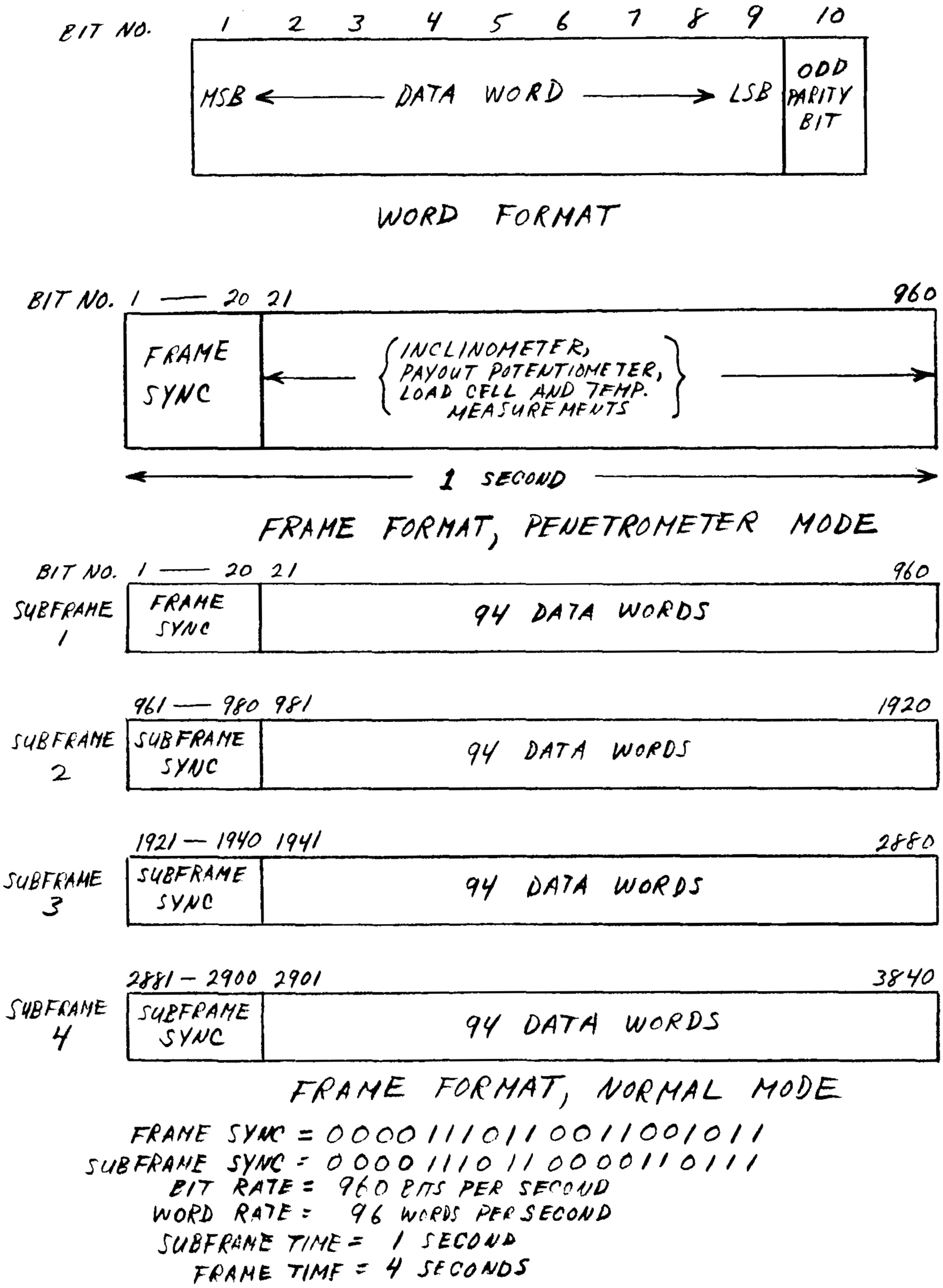


Figure 2.10-4 Telemetry Word and Frame Formats

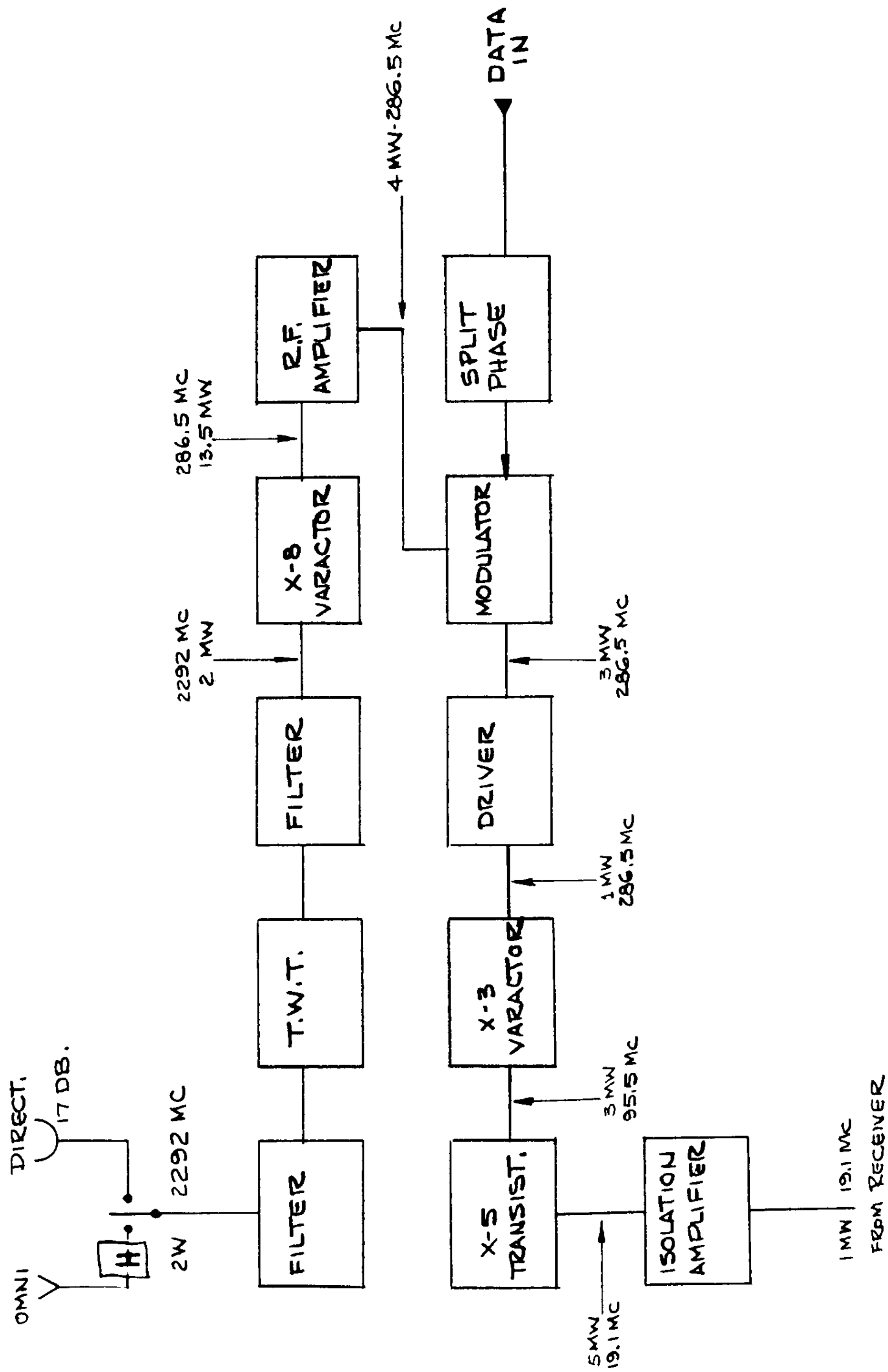


Figure 2.10-5 SLRV Transmitter

final RF amplifier stage will supply the power necessary to drive the X8 varactor multiplier. The RF output power necessary is 13.5 mw to arrive at the required 2 mw input power at 2295 Mc for the TWT. The varactor X8 is divided in two sections: the lumped constant X2, and the stripline X4. The output of the TWT is fed through an RF switch to a square hybrid. The hybrid will be part of the stripline package. The hybrid will provide a minimum of 40 db of isolation between the receiver and transmitter ports. The use of hybrid has the additional advantage of achieving simultaneously an equal power split and a 90^{o} phasing between the outputs to be fed to the two elements of the crossed-bent dipole antenna.

The critical components selected are Hughes 314H TWT tube with a Watkins Johnson WJ 237 used as a backup and a Microwave Associates MAH322B1 varactor. Use of stripline techniques for RF circuitry to minimize weight has also been selected.

The transmitter has the following parameters:

Size: 4" x 8" x 4"

Weight: 2.9 lb

Power: 8.48 watts.

2.10.3 Command Receiver

The block diagram of the receiver is shown in Figure 2.10-6. Modulation characteristics of PM Carrier, FSK Subcarrier, and 48 bps split phase data, have been selected. However, to eliminate any possibility of interactions between Surveyor and SLRV commands, the FSK subcarrier frequency is 5 kc instead of 2.3 kc as for Surveyor.

The receiver uses stripline for RF filtering, a balanced mixer, and times 6 multiplier which furnishes the 2062.8-Mc LO signal.

IF amplification is accomplished at 47 Mc and 9.5 Mc. A chain of multipliers which receives its power from a 9.55-Mc VCO, provides 38.2 Mc for the second mixer, 343.8 Mc for the stripline unit, and 9.55 Mc for the phase detector. The phase detector, operational amplifier, and VCO form a phase locked loop. No provision for frequency search is provided since this is available from the ground.

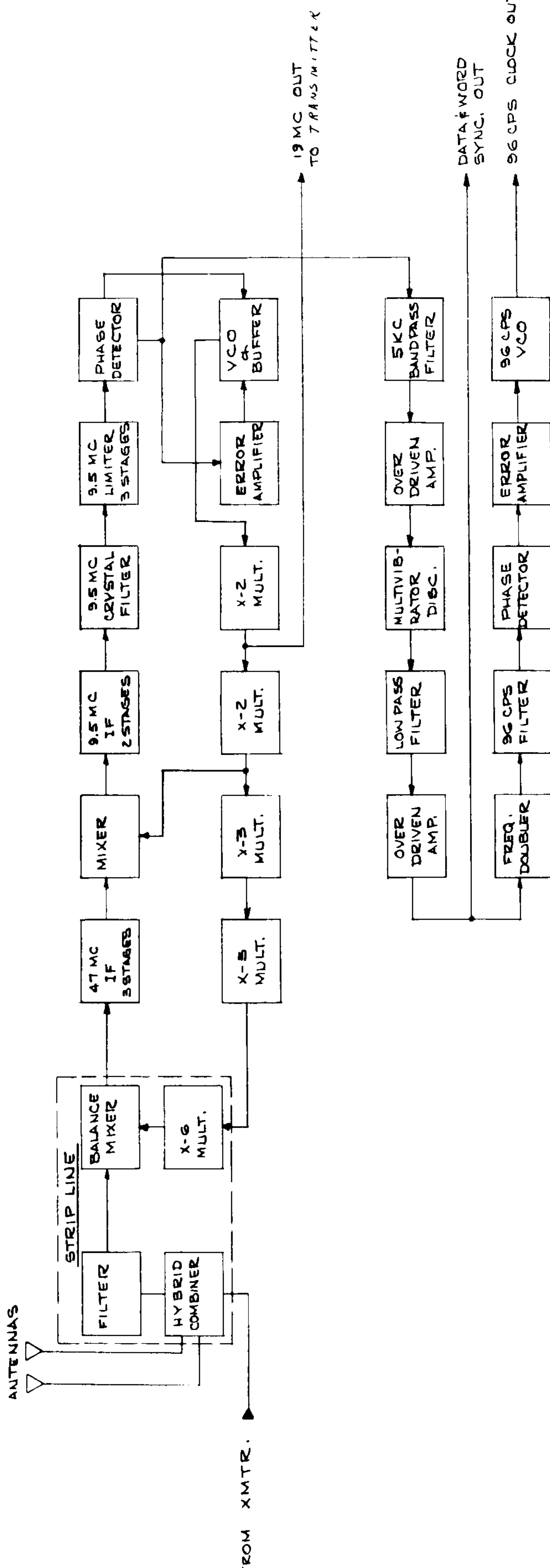


Figure 2. 10-6 Command Receiver Block Diagram

The baseband signal from the phase detector is filtered, limited, and detected in a multivibrator-type discriminator. The resultant split phase PCM signal is filtered and limited in an overdriven amplifier and passed to the decoder as data.

Receiver parameters are:

Size: 1-1/2" x 6" x 4"

Weight: 1 lb

Power: 1.3 watts.

2.10.4 Antennas

Two communication antennas on SLRV are required to meet the functional requirement. The general schematic of antenna interconnection is shown in Figure 2.10-7. A square hybrid duplexer is used between the transmitter and the receiver at the omnidirectional antenna. An RF transfer switch is used to alternate the transmitter between the omnidirectional and a directional antenna.

The omnidirectional antenna configuration is shown in Figure 2.10-8. It will have a coverage cone of $\pm$ 121.5^{o} giving a + 3-db gain at the center and - 6-db loss at 121.5^{o}.

Construction comprises two bent, crossed, quadrature-fed dipoles mounted above an appropriately dimensioned groundplane: a circular polarization is realized. The weight of the antenna is approximately 8 oz.

The directional 17-db gain antenna construction is shown in Figure 2.10-9. The antenna is constructed from perforated aluminum 0.05" thick. It is 18" in diameter, has a beam width of 20^{o} at 3-db points, and has circular polarization. A two-crossed-dipole feed is used. The dish weighs 8 oz and the feed weights 5 oz.

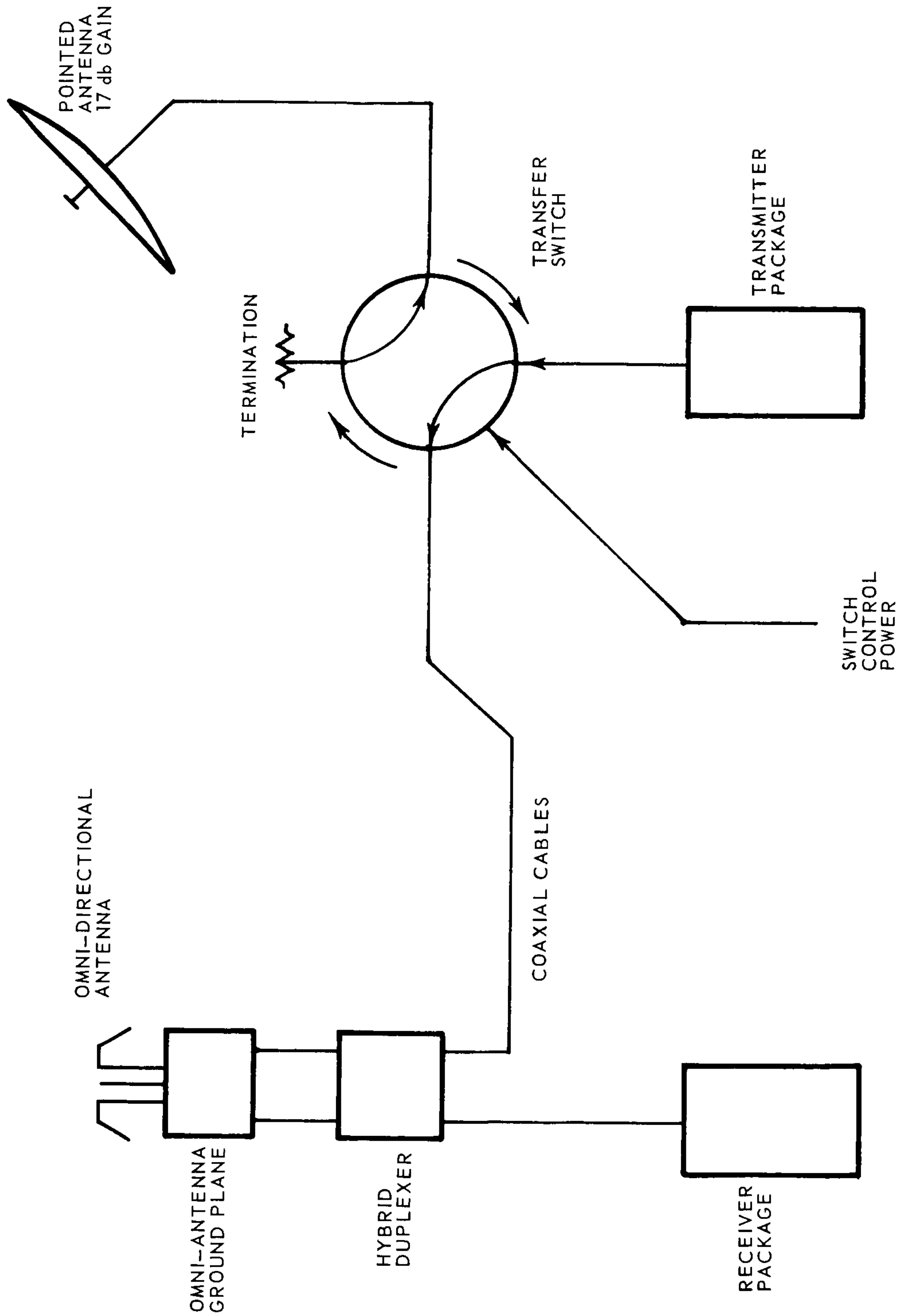


Figure 2.10-7 General Schematic of R F Circuitry

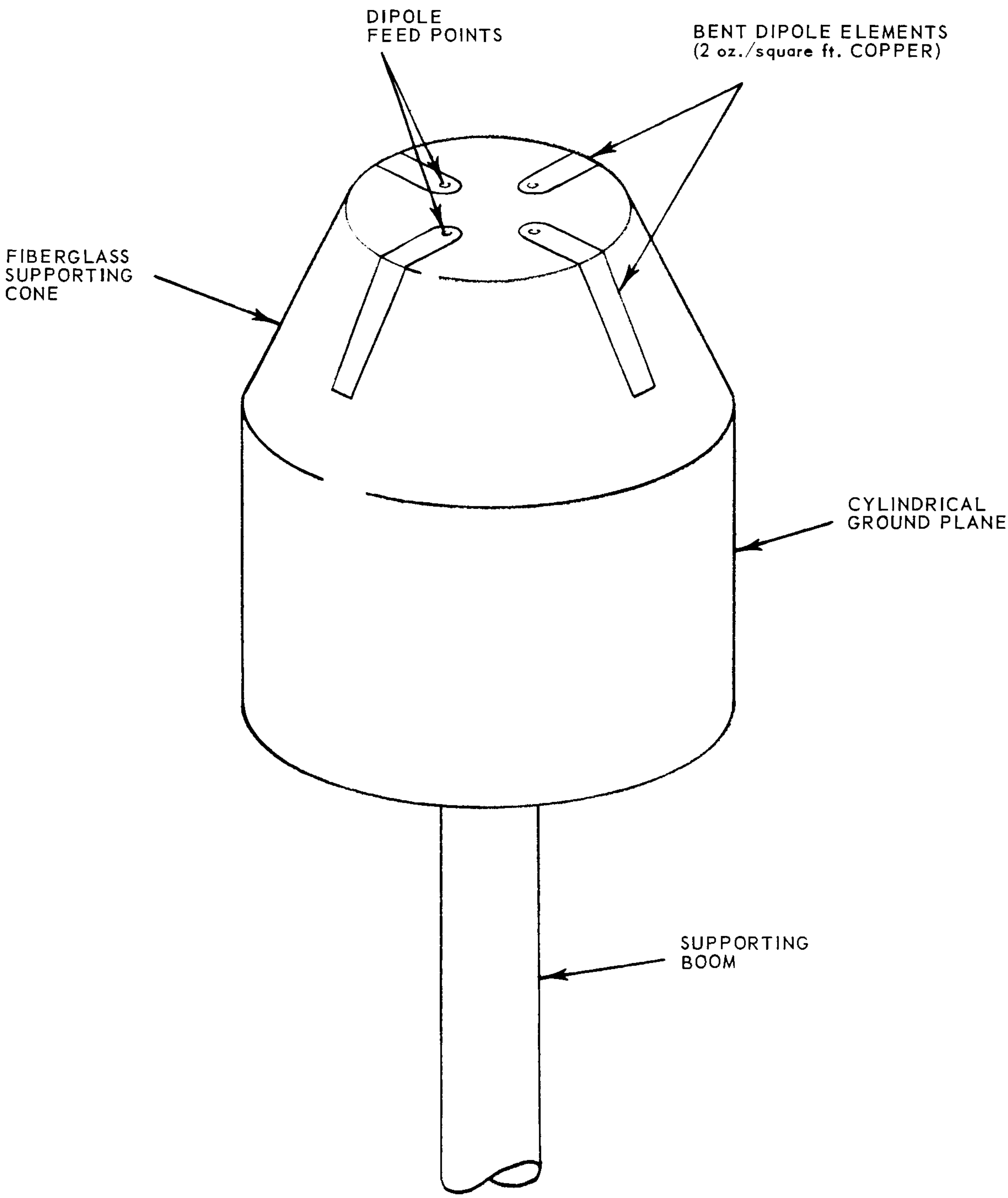


Figure 2. 10-8 S-Band Omnidirectional Antenna

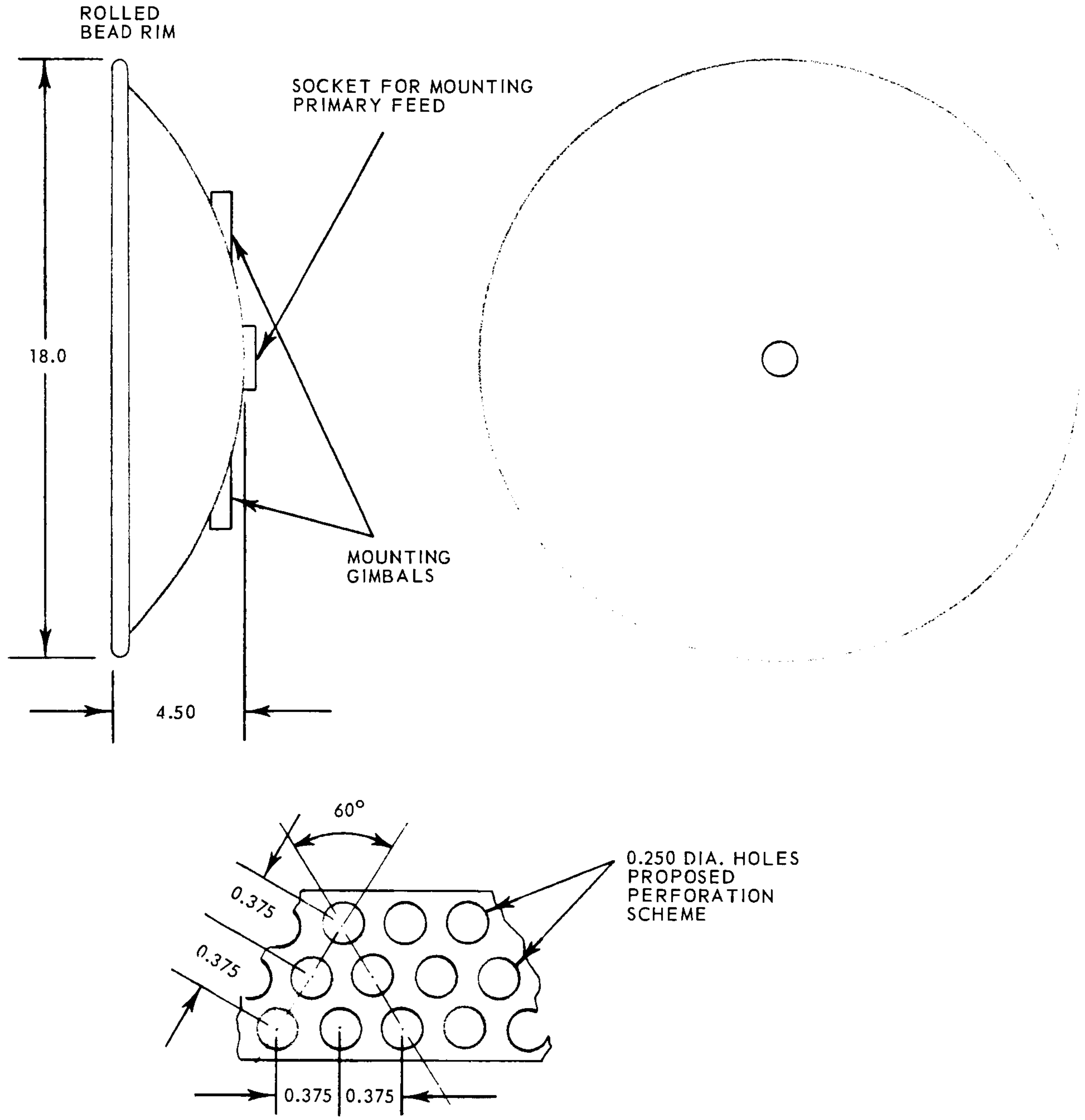


Figure 2. 10-9 17 db Pointed Antenna

2.11 PRIMARY POWER SUPPLY

The SLRV power supply will consist of a radioisotope thermoelectric generator (RTG), a power converter, and a shunt power regulator. The RTG converts heat to electric power through the natural decay of a radioisotope and a series of thermocouples. The power converter is a static transistor converter which transfers the input power to all the subsystems at the desired voltages. The power regulator maintains RTG power at a constant level and output voltages within the desired tolerance for all normal modes of operation.

The RTG will provide 38.8 watts at the end of mission with a power contingency allowance of 3.1 watts. The power regulator will maintain the RTG output voltage at 6 volts throughout the complete mission.

The DC-DC power converter transfers the power to the loads as shown in Figure 2.11-1, and Table 2.2-5. The RTG weights 21 lb. and the converter weighs 3.7 lb.

2.12 TELEVISION

A functional diagram of the television is shown in Figure 2.12-1.

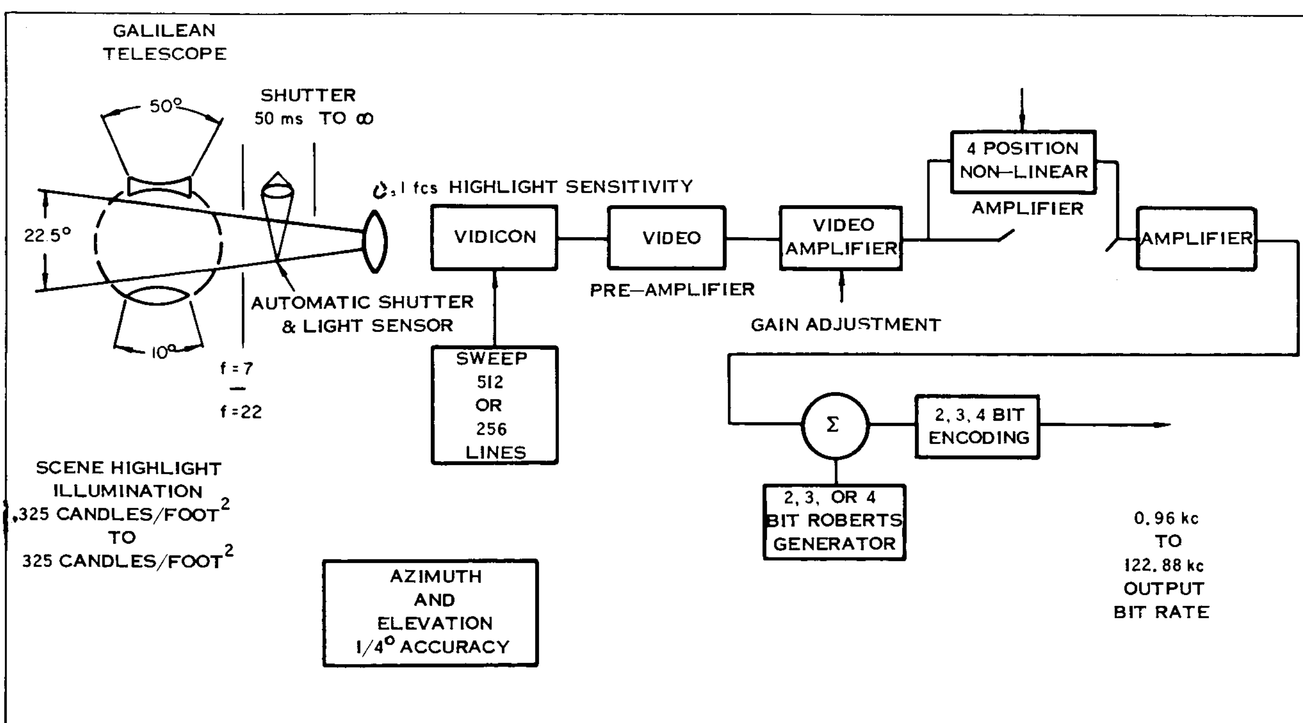
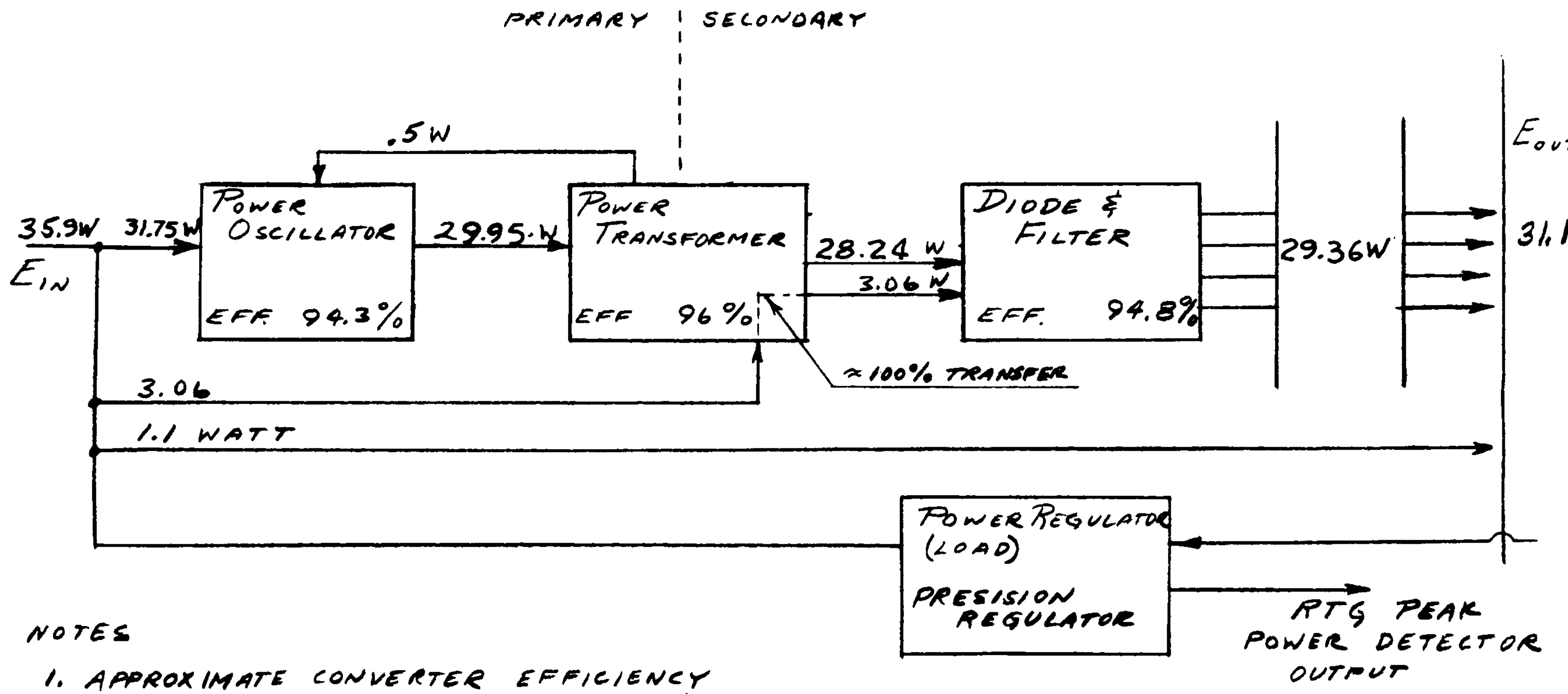


Figure 2.12-1 Television Functional Block Diagram



NOTES

1. APPROXIMATE CONVERTER EFFICIENCY
$\eta = 94.3 \times 96 \times 94.8 = 85.7\%$

2. RTG POWER ESTIMATE AT 80% CONVERSION EFFICIENCY AND ALL POWER THROUGH THE CONVERTER
$\frac{P_{OUT}}{\eta} = \frac{31.1}{.80} = 38.8$ WATTS

3. POWER SAFETY FACTOR $38.8 - 35.9 = 2.9$ WATTS

Figure 2.11-1 Converter Schematic Diagram

The optical elements of the system provide three fields of view and consist of a Galilean telescope which is mounted in front of the fixed lens having a 22.5-degree field of view. The telescope is rotated 180 degrees ($\pm 90^{o}$) to obtain either narrow (10 degree) or a wide (50 degree) field of view. In the middle position the telescope is not used and the fixed field of view (22.5 degree) of the camera sees between the convex and concave lens of the Galilean telescope. Continuously variable f-stops from f/7 to f/22, are provided. Shutter speeds from 50 ms to a maximum time at the operator option are also provided. A partially silvered mirror placed between the iris and the shutter reflects a small percentage of the light to a photo diode which is used for both light measurement and, if desired, automatic exposure.

A vidicon having electrostatic focus and deflection and long retentivity characteristics is used as the basic light transducer. A highlight sensitivity of 0.1 ft-candle-second is available in this unit. The vidicon is readout by digitally generated sweep waveforms which have a staircase form. During each flat portion of the horizontal sweep waveform, the vidicon beam is turned on for a 3-μsec period and an elemental area of the vidicon faceplate is readout. The number of elements readout can be varied from $(256)^2$ to $(512)^2$. The readout rate can be varied from 100,000 elements per second to 200 elements per second simply by changing the input clock rate. This flexibility encompasses the range required for encoding data rates of 0.96 kilobit per second or 122.88 kilobits per second at 2, 3, or 4 bits per element, at either $(256)^2$ elements or $(512)^2$ elements per frame. Robert's modulation can be used with any of the foregoing combinations at the discretion of the operator.

The combination of 4 bits per element encoding, $(512)^2$ elements per frame readout, and 122.88 kilobits per second data rate constitutes the high performance mode of the subsystem. The frame time under these conditions is 8.3 seconds. The combination of 2 bits per element encoding, $(256)^2$ elements per frame readout, and 0.96 kilobit per second data rate constitutes the extreme emergency mode. The frame time under these conditions is 137 seconds.

The exposure capability of the variable shutter and iris and the sensitivity of the vidicon are such that 0.24 second is the required exposure time at f/22 and at a maximum lunar surface luminance of 325 candles/ft^2. An exposure time of 24 seconds may be safely assumed as feasible without any picture degradation (the maximum exposure time as limited by the vidicon faceplate is much longer but would require experimental verification). The highlight luminance level required at this long exposure time is 0.325 candles ft^2. Thus the highlight dynamic range of the subsystem is 10^3:1. The tone scale capability of the system is such as to articulate ten 3-db grey levels except when operating in the emergency mode or with long exposure times.

The power requirements of the television subsystem vary depending on the operating mode. The minimum is 2.88 watts required for standby during lunar day and for nighttime survival. The maximum is 5.2 watts required while reading out.

The angular freedom in azimuth is $\pm$ 200 degrees and in elevation is + 15 degrees and - 60 degrees. The position of the line of sight is controlled by elevation and azimuth drives which have readout capabilities of $\pm$ 0.248 degree peak, respectively.

The subsystem possesses a semiactive thermal control system which maintains the interior temperature in the range of + 125°F to - 40°F non-operating and + 125°F to + 50°F operating.

A view of a full scale model of the SLRV-TV subsystem is shown in Figure 2.12-2.

Table 2.12-1 gives a weight summary for the design.

TABLE 2.12-1

DESIGN WEIGHT SUMMARY

Element	Weight (lb)
Camera proper	2.89
Field changing optics	0.90
Elevation and azimuth drives	2.37
Remaining structure	1.47
Total	7.63 lb

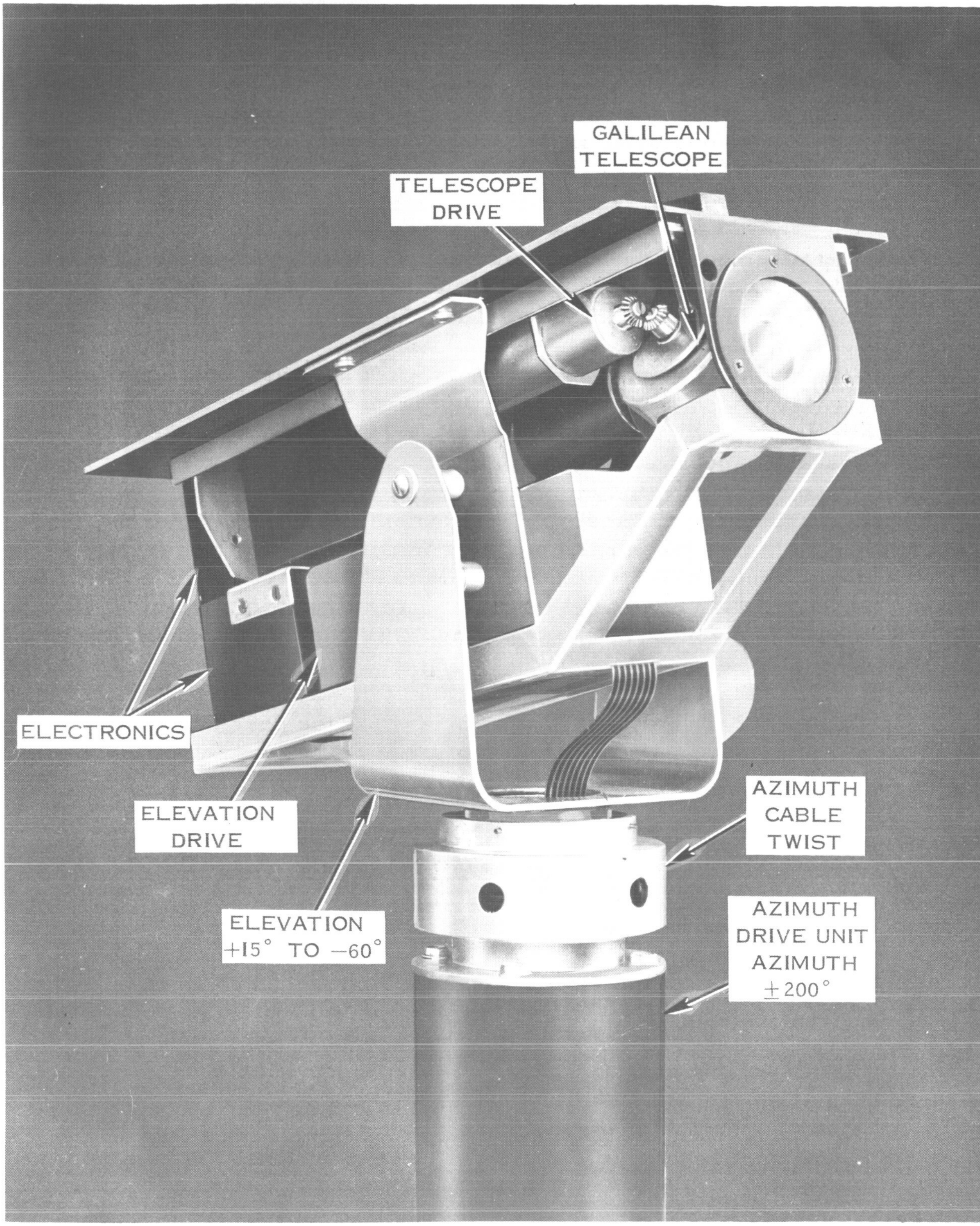


Figure 2.12-2 Full Scale Model of TV Subsystem

2.13 THERMAL CONTROL

The thermal control method chosen for SLRV is essentially passive. Specifically, control is achieved via insulated electronic compartments, thermal radiation shields, resistance heaters, and application of selective thermal coatings at the more sensitive areas. This method of control is inherently reliable and light in weight.

Temperatures have been calculated at many points throughout the SLRV for several different phases of the mission; including transit, lunar day operation, and lunar night. Lunar day operation was further broken down to early morning operation (sun 13° above horizon), mid-morning operation (sun 45° above horizon), mid-day (sun at zenith), and mid-afternoon. Some allowance was made for the vehicle position relative to the sun rays. Temperatures calculated are summarized in Table 2.13-1.

Thermal control of the electronics compartment will be accomplished with a metalic plate to which all electronic components are mounted. On the sides and bottom of the compartment heat transfer will be virtually eliminated by use of superinsulation. Control within the electronic compartment will be achieved by providing a single thermal path through the top plate. The thermal path through the thermal plate is further modified by applying their coatings to the outer surface. During the lunar night, auxiliary heaters will be used to maintain minimum acceptable temperatures.

The TV camera package thermal control will be similar to that described above for the electronic compartment in that it will use a single thermal plate and be enclosed with superinsulation.

Thermal insulation is located between the RTG and the Surveyor Spacecraft to minimize the thermal input to the spacecraft.

2.14 DSIF/SFOF

Ground operating equipment (GOE) performs the functions of vehicle control, performance monitoring, and collection and analysis of survey data. Ground operating facilities supporting SLRV operations will consist of a combination of existing and planned DSIF and SFOF facilities augmented by SLRV mission-dependent equipment. This section summarizes the DSIF/SFOF configuration required to support the SLRV and the SLRV mission-dependent equipment that must be added. Additional detail regarding DSIF/SFOF configuration trade-offs and special purpose SLRV GOE may be found in Book 2, Volume III, Section 13.

TABLE 2. 13-1

TEMPERATURE DATA

NODE		Transit(^{o}F)	Lunar Day (May) (^{o}F)	Lunar Night (^{o}F)
4	Directional Antenna		138	-108
5	Electronics Mtg Plate		128	22
16	Penetrometer		123	25
17	Transmitter		138	40
21	Inclinometer		133	31
22	Odometer		121	23
26	Structure Front		143	32
31	Structure Rear		260	188
33	Structure Rear Bottom		315	278
37	Front Strut		116	-52
43	Track Hub - Front		108	-68
46	Tread Top - Front		191	-142
54	Track Hub - Rear		103	-62
56	Tread Top - Rear		195	-114
	TV Camera			

Note: All temperatures are equilibrium values.

TABLE 2. 14-1

GROUND OPERATING EQUIPMENT AND FACILITIES FOR SLRV MISSIONS

Location	Mission Dependent (contractor provided)		Mission Independent (JPL provided)	
	Surveyor CDC (Hughes)	SLRV (Bendix)	Existing or Planned	Additional Requirement
SFOF	1. Command subsystem modified for remote electrical input into the command register and provisions for remote transmit control.	1. Vehicle Control Console 2. Survey Control Console 3. Vehicle Systems Monitoring and Control Console 4. Data Reconstruction Unit 5. TV Data. Processor 6. Input Signal Monitoring Console 7. Automatic command Word Generator 8. Command Decoder 9. Photogrammetric analysis equipment 10. Photometric analysis equipment A. Computer programs peculiar to SLRV operations.	1. Computer Complex operating in Mode II-A. 2. Tape recorders and reproducers. 3. Time reference 4. SFOF Media Conversion Equipment modified for SLRV digital TV input. 5. SFOF Storage/ Retrieval and Photographic Processing Systems 6. X-Y Plotters 7. Mission Status Displays 8. Surveyor landing area photo mosaic 9. Closed circuit TV Systems 10. Mission Control facilities 11. SFOF control and monitor facilities 12. DSIF control and monitor facilities 13. SLRV Space Science Area 14. SLRV Performance Analysis Area 15. Microwave link from Goldstone to the SFOF	1. Microwave terminal equipment to receive SLRV digital data. 2. Digital data link to transmit SLRV command data to Goldstone at 48 bits per second.
Goldstone DSS	1. Command subsystem modified for remote input into a separate SLRV SCO. 2. TM processor adjusted for SLRV data rate and format.	1. Data reconstruction unit. 2. TV Data Processor 3. TV Monitor	1. 210' S-band antenna 2. GSDS S-band receiver with wide band phase detector 3. GSDS S-band transmitters with phase modulator 4. Time reference 5. Tape recorder 6. Station control and monitoring facilities.	1. Microwave terminal equipment to transmit SLRV digital data. 2. Digital data terminal to receive SLRV command data from the SFOF.

Limitations of the 100-lb SLRV telecommunications system preclude the reception of telemetry data with an 85' ground antenna while the vehicle is moving. Therefore, the corresponding DSIF/SFOF operational configuration is limited to the use of the Goldstone 210' antenna for data acquisition. Transmission of telemetry to an 85' ground antenna via the vehicle's directional antenna is possible with the vehicle stopped. Thus vehicle status will be monitored during standby operations from the Deep Space Stations (DSS) at Woomera and Johannesburg.

2.14.1 Operational Configuration

A preliminary DSIF/SFOF operational configuration using only the Goldstone Deep Space Station (DSS) is shown in Figure 2. 14-1. Table 2. 14-1 shows the estimate of the distribution of required equipment and facilities for the configuration of Figure 2. 14-1.

In general, all command generation, data collection, and data analysis will occur at the SFOF. The Goldstone DSS will be used to transmit commands, receive and relay data, and provide a backup data recording and command generation capability. Sufficient data processing should be included at Goldstone to permit local monitoring of data quality.

2.14. 1. 1 Data Handling

Data from the SLRV are received at the DSS in the form of split phase PCM/PM with no subcarrier. Telemetry and TV data are received alternately at rates of 960 bps and 122. 88 kbps respectively. Both forms of data are recovered and reconstructed at the DSS using the existing wide-band phase detector plus a special purpose SLRV data reconstruction unit. Reshaped digital data are then relayed to the SFOF in real-time via the existing microwave link. At the SFOF the raw data from the microwave link are again recovered and reconstructed and TM data are routed directly to the computer complex while TV data are routed to a special purpose TV data processor.

On-line utilization of the SFOF computing complex will be required to support SLRV operations in the area of telemetry frame and work synchronization and decommutation. The recommended operating mode is II-A as described in EPD-23. SLRV television data will be routed by the data reconstruction unit to a special purpose TV data processor which will establish frame and line sync, remove the Roberts' modulation from the video, and provide dark current correction of the video signal if necessary.

Outputs from the TV data processor will consist of digital signals specifying the position of the present picture element, analog video, and an unblanking signal. These signals will be routed to a vehicle control console, survey control console, input signal monitor console, and to the SFOF media conversion equipment for scan conversion and permanent photo recording. Reference data for each TV frame will be derived by the computer from the telemetry frames preceding the TV frame and routed to the necessary displays and photo recording equipment.

The planned SFOF photo recording, processing, and storage and retrieval facilities (as described in JPL specifications FOT 5-720 and FOT 5-730) will provide permanent archival storage of SLRV TV data, negative or positive transparencies for off-line photometric and photogrammetic analysis, and copies of SLRV TV images for members of the scientific community.

2.14.1.2 Control Consoles

Four control consoles are presently anticipated to support SLRV operations:

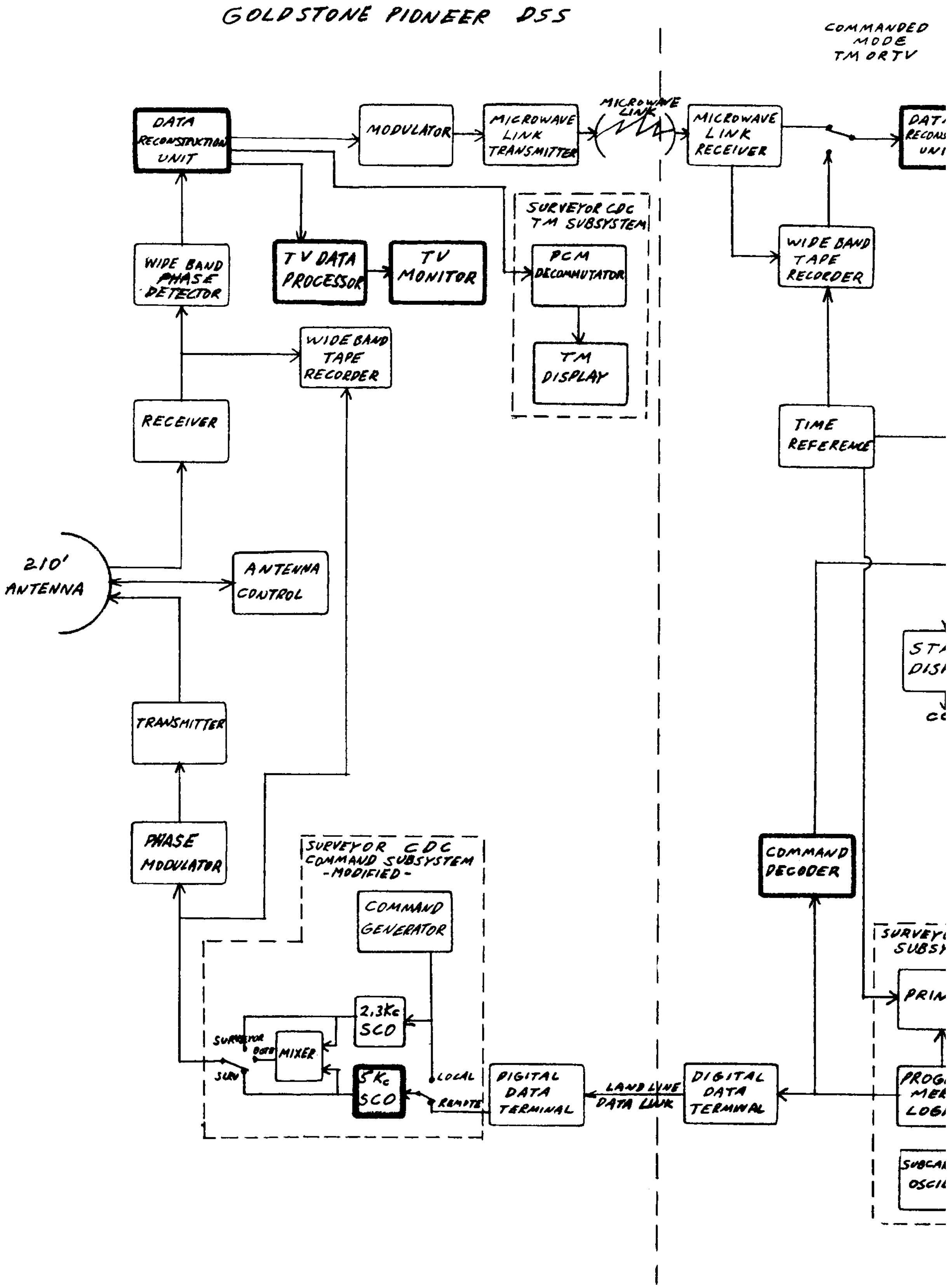
1. Vehicle Control Console, see Figure 2.9-2

2. Survey Control Console, see Figure 2.14-2

3. Vehicle Systems Monitoring and Control Console

4. Input Signal Monitor Console.

All vehicle control (driving) functions are handled at the vehicle control console. The main display is a composite of computer generated synthetic data and TV video. Necessary navigation data are shown as range and bearing to the next destination. The composite display is generated by rear-projecting a video image from a positive transparency and synthetic data from a CRT on a common viewing screen. The positive transparency is produced by a self-contained photo recorder, rapid processor, and projector unit which makes the video data available for display within 10 seconds after transmission is complete. The CCTV monitor to the left of the main display will be connected to the SFOF CCTV system and is intended specifically to permit the operator to monitor the following items:


GOLDSTONE PIONEER DSS
COMMANDED MODE TM OR TV
DATA RECONSTRUCTION UNIT
MODULATOR
MICROWAVE LINK TRANSMITTER
MICROWAVE LINK
MICROWAVE LINK RECEIVER
SURVEYOR CDC TM SUBSYSTEM
PCM DECOMMUTATOR
TM DISPLAY
TV DATA PROCESSOR
TV MONITOR
WIDE BAND PHASE DETECTOR
WIDE BAND TAPE RECORDER
WIDE BAND TAPE RECORDER
TIME REFERENCE
RECEIVER
210' ANTENNA
ANTENNA CONTROL
TRANSMITTER
PHASE MODULATOR
SURVEYOR CDC COMMAND SUBSYSTEM -MODIFIED-
COMMAND GENERATOR
2.3Kc SCO
MIXER
5Kc SCO
SURV
LOCAL
REMOTE
DIGITAL DATA TERMINAL
LAND LINE DATA LINK
DIGITAL DATA TERMINAL
COMMAND DECODER

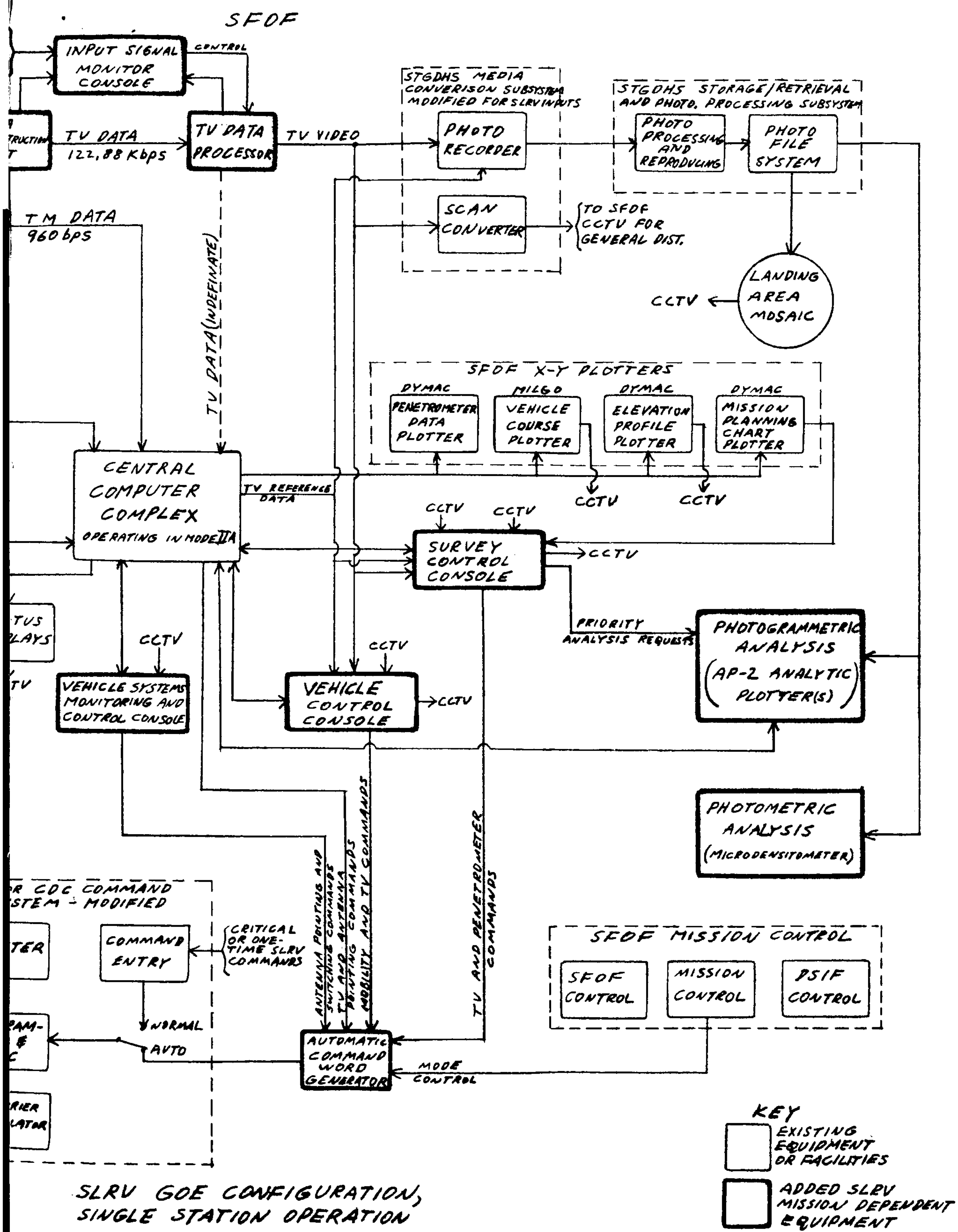


Figure 2.14-1 GOE Configuration for Single-Station Operation

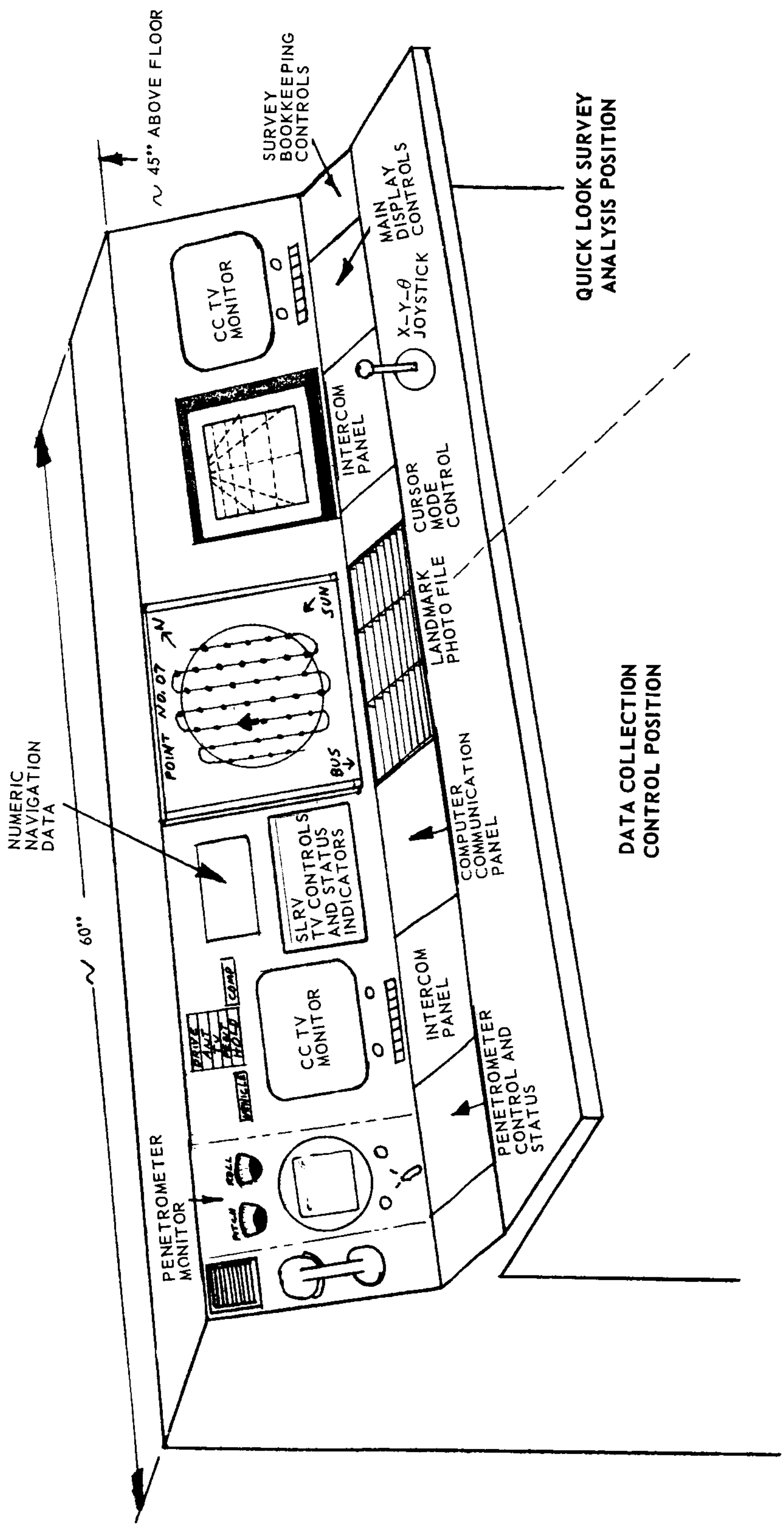


Figure 2.14-2 Survey Control Console

1. Scan converted SLRV TV photos

2. Navigation status plot

3. Vehicle systems status display.

Vehicle mobility commands are generated by operation of either the main steering control or the auxiliary mobility controls. The main steering control is a seven-position, self-centering control stick. In the normal driving mode, the position of this control stick will cause hybrid commands to be encoded and transmitted to the vehicle at 0. 5-second intervals. Auxiliary mobility controls will be provided to implement alternate modes of vehicle mobility control. The cursor control is provided to permit the operator to scale features on the main display in conjunction with his hazard identification task.

The survey control console is a two-position unit accommodating the functions of survey data collection, quick-look data analysis, and navigation position fixing via landmark sighting. The main display at the quick-look survey analysis position is identical to the main display at the vehicle control console except for different synthetic data. The cursor control (joystick) is again used to scale the video picture but this time to determine that the area is acceptable for LEM landing. The display in the center of this console is a navigation status plot consisting of a transparent chart showing the required data locations within a point (or the required point locations within the site) and the present position and heading of the vehicle.

The vehicle systems monitoring and control console will permit status monitoring and control over the vehicle's directional antenna. In general, the required displays will consist of computer driven status and warning lights, analog meter indicators, and numeric displays. A computer controlled page printer and perhaps an oscillographic recorder may be required to supplement this console.

The input signal monitor console is concerned with operation of the data reconstruction unit and TV data processor.

2. 14. 1. 3 SLRV Command Generation Procedures

Closed-loop driving and efficient use of mission time require a fast, automatic command generation procedure under the cognizance of the

Mission Director. A Surveyor CDC command subsystem modified for remote command word entry can be used at the SFOF to generate command words in the same format as for Surveyor. Referring to Figure 2. 14-1, an automatic mode is added to the present command entry facilities of the CDC, referred to as normal mode in Figure 2. 14-1.

The automatic command entry mode uses an automatic command work generator to assemble 10-bit command words for presentation to the CDC programmer. The word generator receives inputs from the vehicle control console, the survey control console, the vehicle systems console, and the computer complex via the 7288 data channel. These inputs are monitored in accordance with the selected automatic mode and the appropriate command is encoded and presented to the CDC each half second. The CDC automatically transmits each command presented at the output of the work generator and will not of itself insert fill-in commands.

Commands entered automatically are limited to those pertaining to vehicle control, antenna pointing and switching, TV operational control, and penetrometer operational control. Others are entered into the CDC in the normal manner. These four categories will be established as separate modes to be changed only upon authorization of the Mission Director. In addition, a HOLD mode will be included which will prevent transmission of operational commands to the vehicle via the automatic command word generator. This HOLD mode could also be used to stop the vehicle in the event of emergency. A change between normal and automatic command entry modes should require the authorization of the SLRV Mission Director.

Commands generated by the CDC at the SFOF are relayed in the form of digital data at 48 bits per second to another CDC at Goldstone via a new land line data link. The CDC at Goldstone should be notified (Figure 2. 14-1) to include an additional SCO and mixer as well as a switch to select either the Surveyor, SLRV, or both SCO's. These simple modifications to the CDC command subsystems at SFOF and Goldstone would provide a versatile command generation facility suitable for both Surveyor and SLRV missions.

2.14.1.4 Data Analysis Equipment

Additional equipment must be provided at the SFOF to permit photogrammetic analysis and perhaps photometric analysis of SLRV TV data. The requirement for photogrammetic analysis equipment in support of landing point verification will require one or more analytic plotter systems of the AP-C or AP-2 variety. Procedures for detailed photometric analysis of SLRV TV data are not yet defined; a microdensitometer may be required.

2. 14. 2 Standby Status Monitoring Configuration

A DSS configuration for SLRV standby status monitoring is shown in Figure 2. 14-3. This configuration will be required at each of three Deep Space Stations. No additional SFOF capability is required for this operation beyond the existing capability for receiving telemetry data via the teletype network.

2.15 OPERATIONAL SEQUENCE

The operational sequence is generated to detail SLRV expected experience during three significant periods:

1. AMR Operations
2. Transit Operations
3. Lunar Operations.

AMR operational sequence is based upon estimates of local requirements, Surveyor requirements, and on Bendix plans for SLRV testing. Transit operational sequence is based upon Atlas-Centaur and Surveyor operations with the possible addition of SLRV in-transit checkout, if desirable and if permitted. Lunar operational sequence is based entirely upon lunar surface operation requirements and the capabilities and performance characteristics of the SLRV.

2.15. 1 AMR

A basic schedule of activities at AMR has been generated (Table 2.15-1) to serve as a basis for operation planning. This schedule allows 64 days at AMR before launch. Some variability in the dates assigned for test completion is allowed. The later portion of the schedule is arranged to minimize the duration of operation with the RTG fuel capsule installed.

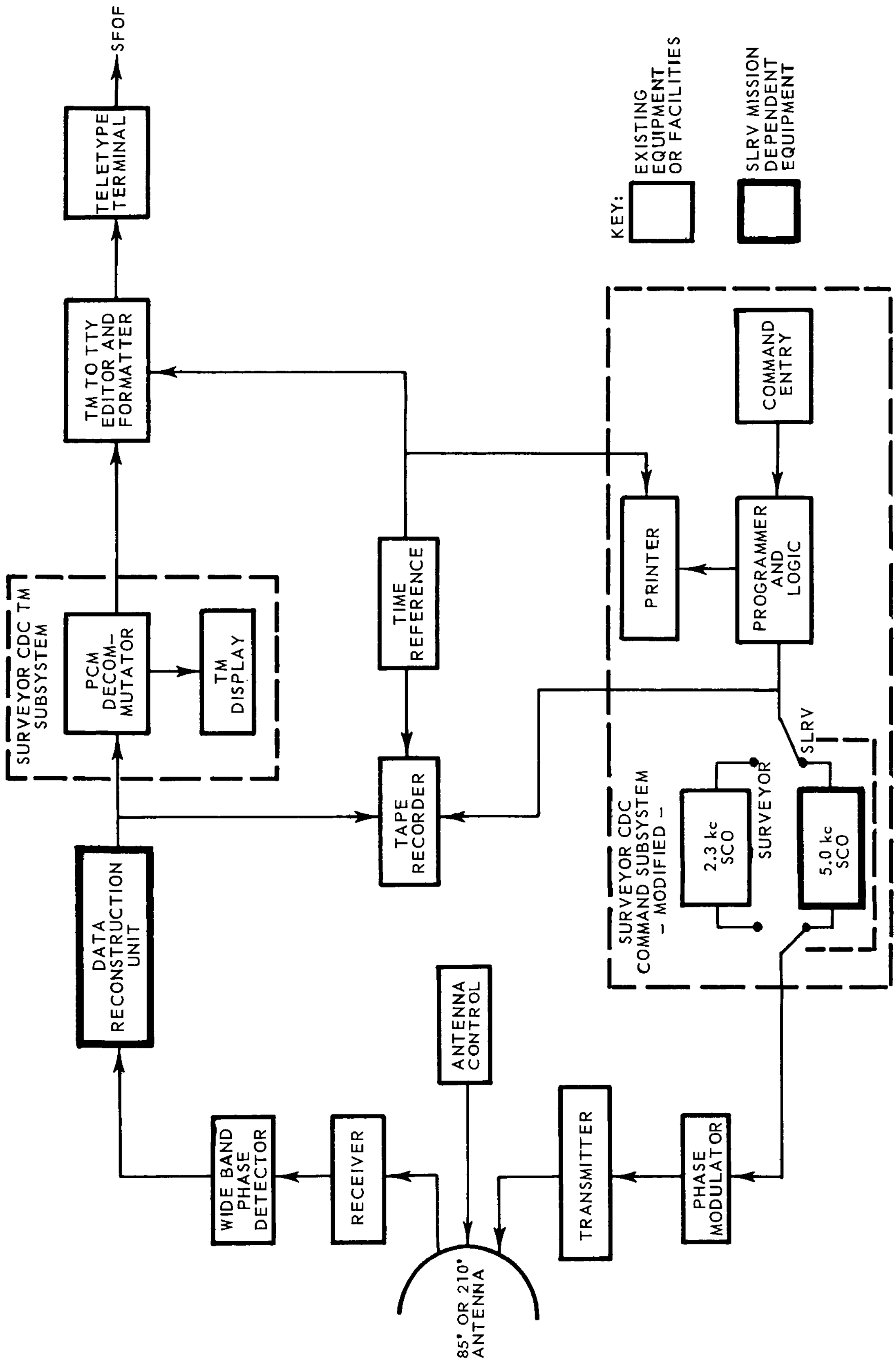


Figure 2.14-3 DSS Configuration for SLRV Stand-by Status Monitoring

TABLE 2.15-1

AMR SCHEDULE OF ACTIVITIES

Time (days before launch)	
-64	Received at AMR
-58	Receiving Inspection Complete
-54	Simulated Mobility Test Complete
-52	Command and Control Test Complete
-47	Telemetry Test Complete
-45	Power Tests Complete
-43	Experiment Tests Complete
-40	Navigation Equipment Tests Complete
-25	Optical Alignment and Calibration Complete
-20	Telemetry Calibration Complete
-15	Final Assembly and Flight Preparation Complete
-13	RTG Fuel Installation Complete
-11	Final Confidence Test Complete
-10	Pyrotechnic Installation Complete
-10	Final Preparation for Surveyor Installation Complete
-8	Installation and Checkout with Surveyor Complete
-7	Surveyor Weight and Balance Complete
-6	Fairing Installation Complete
-5	Final Confidence Check Complete
-5	Move to Launch Pad
-3	Mate with Centaur Complete
-2	Prelaunch Confidence Test Complete
-2	Initiate System Monitoring During Countdown
0	Launch

An operational sequence has been prepared to cover the expected activities of AMR. This sequence (Section 2.16 of this volume) is a functional flow and no time scale is shown. However, the functional flow information is consistent with the above basic schedule.

2.15.2 Transit

A standard sequence of events has been published (EPD-180) which covers the expected operations of Atlas/Centaur, Surveyor, and SFOC. The transit operational sequence of the SLRV is minor compared with this standard sequence but it is expected that the telemetry (T/M) data from the SLRV can be relayed to earth as a portion of the scheduled engineering interrogation procedures. Command inputs to the SLRV and T/M outputs, both through the umbilical connector have been provided to facilitate the data transfer. The SLRV T/M can scan the entire SLRV T/M data (3840 bits) and can readout these data to the DSIF within 4 seconds.

2.15.3 Lunar Operations

Lunar operations are possible immediately after touchdown. Deployment, checkout, and mission operations should take place as soon as practical to maximize the system information output. As a result of the difference in thermal conditions while traveling through space and after touchdown, a deployment window probably exists. Deployment will be commanded to coincide with the actual optimum condition as determined from T/M data. The initial checkout sequence is detailed is the following listing:

Initail Checkout Sequence

Touchdown

Surveyor "GO" (information from Surveyor sensors indicates "OK to deploy")

SLRV "GO" (ground decision based on sensor trends)

Command "Initial Deploy" (Via Surveyor)

Command "Second Deploy" (Via Surveyor)

Verify "Second Deploy" (Via Surveyor)

Acquire earth link

Exercise earth link

Command "Release TV and Antenna" (Via SLRV T/M)

Exercise TV

Command "Short Range Look-Around" (A computer programmed sequence of close-in TV exposures to examine wheel sinkage, antenna position, vehicle damage, Surveyor condition, Surveyor-vehicle interference, local surface condition)

Command "Penetrometer T/M mode"

Command "Penetrometer Start"

Complete Penetrometer action and transmit

Command "Regular T/M mode"

Initiate "Exercise Mobility" (A programmed sequence of operations and TV exposures which will demonstrate the operation of each function of each mobility element and of the sun sensors and inclinometer)

Initiate "First Look" (An operator-directed series of 3-meter steps encircling the Surveyor at a radius of 20 meters with frequent TV exposure out to the horizon.)

Decision - Select the 3200-meter site

Decision - Select the survey pattern

Decision - Select the 1st survey point

Go the 1st point.

3-Meter Step Sequence

All travel occurs in steps of 3-meter or shorter lengths. Each step is initiated with the antenna switch at "OMNI", Mobility "OFF", TV "OFF".

1. Compute antenna required pointing angles
2. Command antenna bearing angle
3. Command antenna elevation angle
4. Verify antenna pointing
5. Command switch to directional antenna
6. Verify TV status
7. Command TV data mode
8. Command TV expose (for drive) and transmit
9. Decision (See A below if additional TV views are required)
10. Command "T/M data mode"
11. Command "switch to omniantenna"
12. Command "drive"
13. Stop after 3-meter run.

A. If additional TV views are required at this point, introduce the following as many times as necessary.

a. Select required TV pointing angles and FOV

b. Generate pointing commands and FOV command

c. Position TV in azimuth

d. Position TV in elemation

e. Adjust FOV

f. Verify pointing angles and FOV

g. Command TV exposure and transmit

h. Decision.

Note: These additional views are obtained in order to define possible hazards, to seek out general routes, to aid in climbing obstacles, etc.

When a stop (either on a traverse or as a part of a site survey) is used only to obtain drive information, then the sequence of operations is as described above. When the stop is used to obtain survey data, as is done within a point or in making side observations during a traverse between points, then the sequence is that which is described below. The survey positions (L, M, N, ...) are predetermined TV views, essential to the survey, which the computer will call for as required. The computer will be instructed to modify the pointing and FOV as occasioned by the terrain. The initial conditions here are identical with those specified above for the ordinary 3-meter step.

Sequence for 3-Meter Step with Survey Activity

1. Compute antenna required pointing angles
2. Command antenna bearing angle
3. Command antenna elevation angle
4. Verify antenna pointing
5. Command switch to directional antenna
6. Verify TV status
7. Command TV point to survey position (L)
8. Generate TV bearing and elevation pointing and FOV commands
9. Command TV bearing and elevation and FOV pointing commands
10. Verify pointing angles and FOV

11. Command TV data mode

12. Command TV expose and transmit

13. Repeat items 7 through 12 for survey positions

    (M, N, ...) as required

    (If the survey stop is to include penetrometer measurements or sinkage observation, then items 14 through 17 and/or items 18 through 21 may be introduced.)

14. Command TV examine track

15. Command TV bearing and elevation and FOV

16. Verify pointing angles and FOV

17. Command TV expose and transmit

18. Command penetrometer T/M mode

19. Command penetrometer start

20. Complete penetrometer and transmit

21. Command TV data mode

22. Command TV to drive position

23. Verify TV pointing angle

24. Command TV expose (for drive) and transmit

25. Decision (See A below if additional TV views are required)

26. Command T/M data mode

27. Command TV to drive position

28. Command switch to omniantenna

29. Command drive

30. Stop after 30-meter run.

A. If additional TV views are required at this point, introduce the following as many times as necessary.

a. Select required TV pointing angles and FOV

b. Generage pointing commands and FOV command

c. Position TV in azimuth

d. Position TV in elevation

e. Adjust FOV

f. Verify pointing angles and FOV

g. Command TV expose and transmit

h. Decision.

Note: These additional views are obtained in order to better define possible hazards , to supplement mapping operations, to seek out general routes, to aid in climbing obstacles, etc.

2.16 GROUND SUPPORT EQUIPMENT

Ground support equipment (GSE) is extensively covered in this section since there is no additional discussion in Book 2. A GSE plan for SLRV has been prepared based on information gained during the Phase I study. Both the pre-launch operational profile for the SLRV and the installation and support plan for DSIF equipment are included. Recommendations are made for Phase II implementation of the support system requirements.

2.16.1 Requirements

The basic requirements which define the GSE elements are developed through an operations and maintenance analysis of the pre-launch plan for SLRV and of the installation and operation of the DSIF ground operating equipment. This analysis primarily involves a step-by-step definition of the sequential events which take place from final acceptance at the factory through mission completion. Support requirements are then identified for each operational activity. Figures 2. 16-1 and 2. 16-2 illustrate the operational profiles for the SLRV and DSIF equipments. Refinement of the profiles will continue through Phase II until every item of GSE has been defined and until the profiles represent an accurate description of the operation compatible with SLRV design and final mission plans.

2.16.1.1 SLRV Pre-Launch Operation Profile

The SLRV pre-launch operational profile (Figure 2. 16-1) follows the preliminary sequences established for the Surveyor Spacecraft. The SLRV and the modifications required for Surveyor will be delivered to Hughes Aircraft Corporation in Culver City, California for initial installation and integration. In accordance with the Surveyor pre-launch plan, the assembled spacecraft system will then be subjected to combined system tests and simulated launch pad activities with the Centaur Stage at General Dynamics in San Diego, California. Following these tests, the individual systems will be disassembled and shipped to AMR for final checkout, calibration, reassembly, and launch. Two complete systems follow through this sequence; however, one is held at the launch site as back-up in case of failure in the first flight unit.

The SLRV is assembled and acceptance tested at Bendix in its final flight configuration except for explosive devices and the RTG fuel capsule. Installation of the fuel capsule at the last possible moment prior to launch is necessitated as a result of the limited radio active half-life. The preliminary design includes a life expectancy of approximately seventeen days in addition to a ninety-day mission capability. To accommodate this limitation and still retain accuracy in simulation of the power source, an electric heater element is initially installed in the RTG. All testing is accomplished using this heater until final replacement with the active element at AMR. Timing for the final installation is somewhat critical, in that the seventeen-day, excess-life period must be adhered to, including transit time to the moon.

An additional requirement of the RTG design which must be observed is that of limiting the number of heating and cooling-down cycles. This requirement is satisfied in the pre-launch plan by providing standby power to the electric heater continuously through all operations, including shipment.

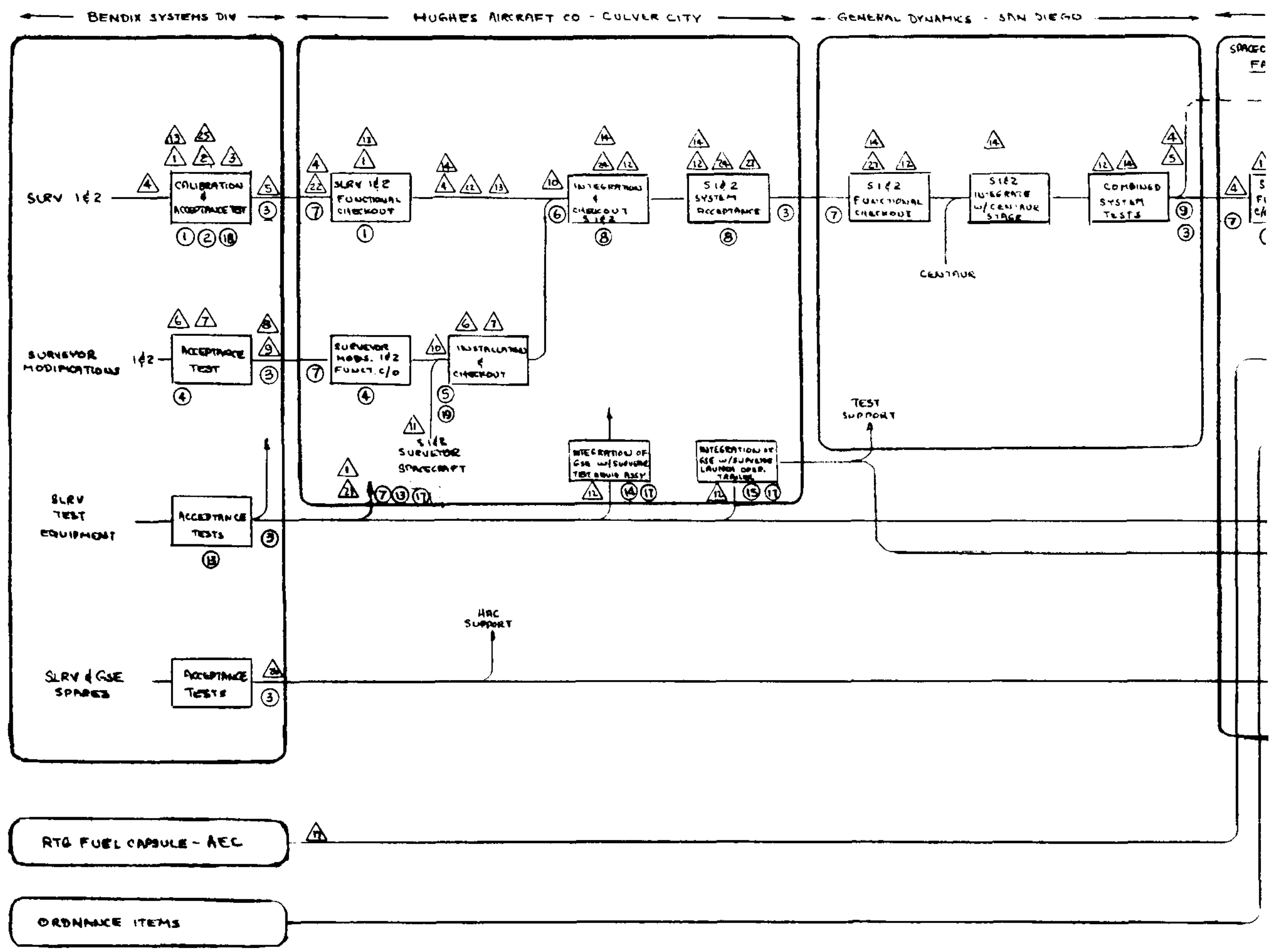
An alternate approach towards solution of the RTG support problem has been considered but temporarily rejected because of estimated test correlation difficulties. This plan suggests use of a test or dummy RTG unit with final replacement of the complete active RTG at the launch site. A final approach towards these problems will be selected during Phase II as more information on the RTG becomes available.

After completing flight acceptance tests at Bendix, the SLRV is shipped to Hughes Aircraft Corporation. A functional checkout is accomplished with the SLRV functional test equipment group at Hughes, prior to integration with the Surveyor Spacecraft.

The structural modifications and the RF ranging transponder are installed on the spacecraft and checked out before assembly of the SLRV. The integration sequences include a mechanical interface check, an umbilical function check prior to mating, and compatibility test of the RF ranging equipments. After mating, functional tests are performed using the Surveyor System test equipment assembly (STEA) supplemented with SLRV control and monitoring equipment. Functional tests of the SLRV after integration with the spacecraft are limited to monitoring of general housekeeping data. Deployment capability is verified through manual release of pull pins installed in lieu of explosive devices.

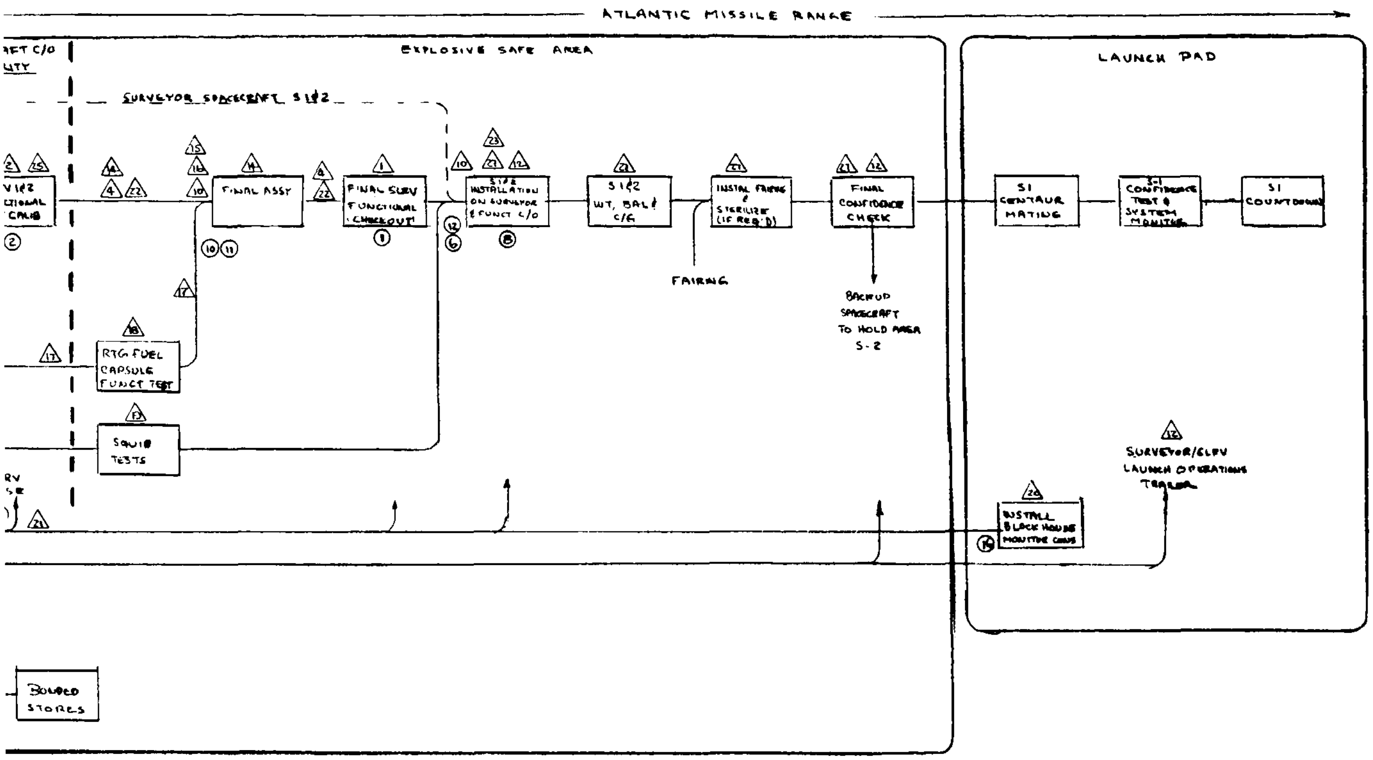
Integration of the SLRV/Spacecraft System with the Centaur Stage at San Diego primarily involves Surveyor interfaces; however, some specific SLRV support problems must be accommodated such as continuation of the RTG electric power source and heat removal. System tests are performed using the Hughes survey launch operations trailer (SLOT) supplemented with SLRV control and monitor equipment.

After completion of combined system tests at General Dynamics, the Centaur, the Surveyor, and the SLRV are disassembled and are packed for shipment to AMR. Upon receipt of the SLRV at AMR, a complete check of calibration and alignment similar to that performed during acceptance tests at Bendix is initiated. This test is performed in the spacecraft checkout facility. Critical optical measurements are performed for the final time before launch to obtain accurate calibration data. The SLRV functional tests will include dynamic tests of mobility functions on the mobility test fixture. It may be required that the test area be RF shielded since transmission of commands and telemetry to and from the SLRV is included as part of the test procedure. Temperature control equipment will also be



Prelaunch Activities

1 SLRV Functional Test
2 Sensor Alignment and Calibration
3 Packing and Shipping
4 Surveyor Modification Functional Test
5 Installation of Mods on Surveyor Spacecraft
6 Installation of SLRV on Surveyor Spacecraft
7 Uncrating and Receiving Inspection
8 Integrated SLRV/Surveyor Functional Tests
9 Disassemble SLRV from Surveyor
10 Install RTG Fuel Capsule
11 Evacuate RTG and Fill with Inert Gas
12 Install Pyrotechnic Devices in SLRV and at Deployment Interfaces
13 GSE Functional Tests
14 Integrate SLRV Supplementary Control and Monitor GSE with Surveyor System Test Equipment Assembly (STER)
15 Integrate SLRV Supplementary Control and Monitor GSE with Surveyor Launch Operations Trailer (SLOT)
16 Install a c/o Blockhouse SLRV Monitor Console
17 Calibrate GSE
18 Wt. Balance and C/G Test
19 Checkout Surveyor Umbilical Functions Prior to Mating SLRV
20 SLRV Cooling (Required Continuously)



△ GSE Requirements

1 SLRV Functional Test Equipment Group
2 SLRV Sensor Alignment and Calibration Equipment
3 SLRV Weight, Balance and Center of Gravity Stand
4 SLRV Handling Equipment
5 SLRV Shipping Container
6 Transponder Test Set
7 Deployment Mechanism Test Fixture
8 Transponder Shipping Container
9 Deployment Mechanism Shipping Container
10 Installation Tools (Common)
11 Surveyor/SLRV Umbilical Function Test Set
12 Supplementary Control and Monitor Equipment for Integration with Surveyor STEA and SLOT
13 SLRV Cooling Equipment
14 RTG Electric Heater Power Supply
15 Vacuum Pump
16 Inert Gas Pressurization Equipment
17 RTG Fuel Shipping Container
18 RTG Fuel Functional Test Equipment
19 Squib Tester (GFE)
20 SLRV Block House Monitor Console
21 Special Calibration Equipment
22 SLRV Transportation Dolly
23 Squib Shorting Plugs
24 Deployment Mechanism Pull Pins
25 Optical Alignment Facility
26 Spares Shipping Containers
27 Surveyor Spacecraft Cooling (HAC)

Figure 2. 16-1 SLRV Prelaunch Operational Profile

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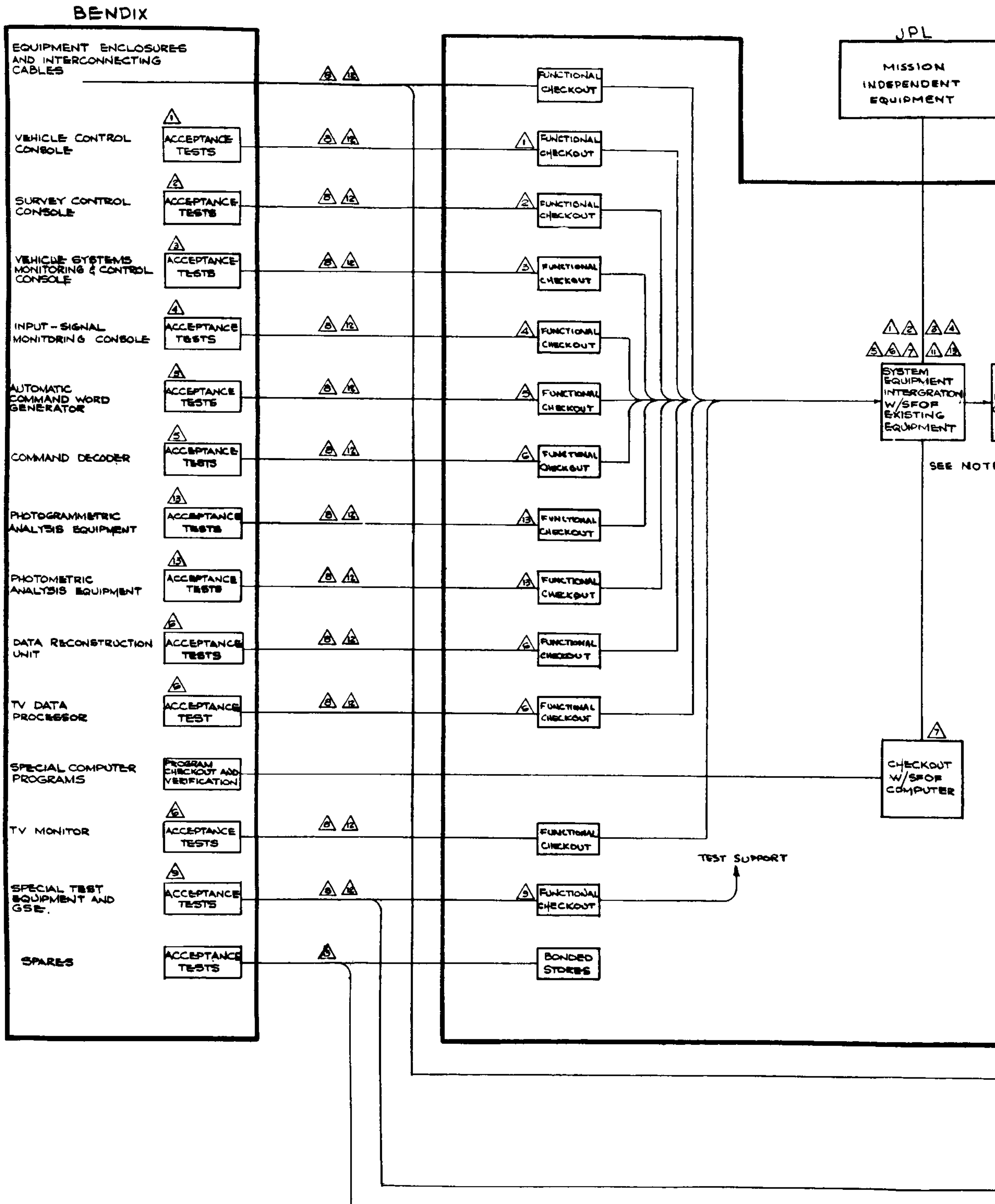

BENDIX
EQUIPMENT ENCLOSURES AND INTERCONNECTING CABLES
VEHICLE CONTROL CONSOLE
ACCEPTANCE TESTS
SURVEY CONTROL CONSOLE
VEHICLE SYSTEMS MONITORING & CONTROL CONSOLE
INPUT-SIGNAL MONITORING CONSOLE
AUTOMATIC COMMAND WORD GENERATOR
COMMAND DECODER
PHOTOGRAMMETRIC ANALYSIS EQUIPMENT
PHOTOMETRIC ANALYSIS EQUIPMENT
DATA RECONSTRUCTION UNIT
TV DATA PROCESSOR
ACCEPTANCE TEST
SPECIAL COMPUTER PROGRAMS
PROGRAM CHECKOUT AND VERIFICATION
TV MONITOR
SPECIAL TEST EQUIPMENT AND GSE.
SPARES
FUNCTIONAL CHECKOUT
BONDED STORES
TEST SUPPORT
JPL
MISSION INDEPENDENT EQUIPMENT
SYSTEM EQUIPMENT INTERGRATION W/SFOF EXISTING EQUIPMENT
SEE NOT
CHECKOUT W/SFOF COMPUTER

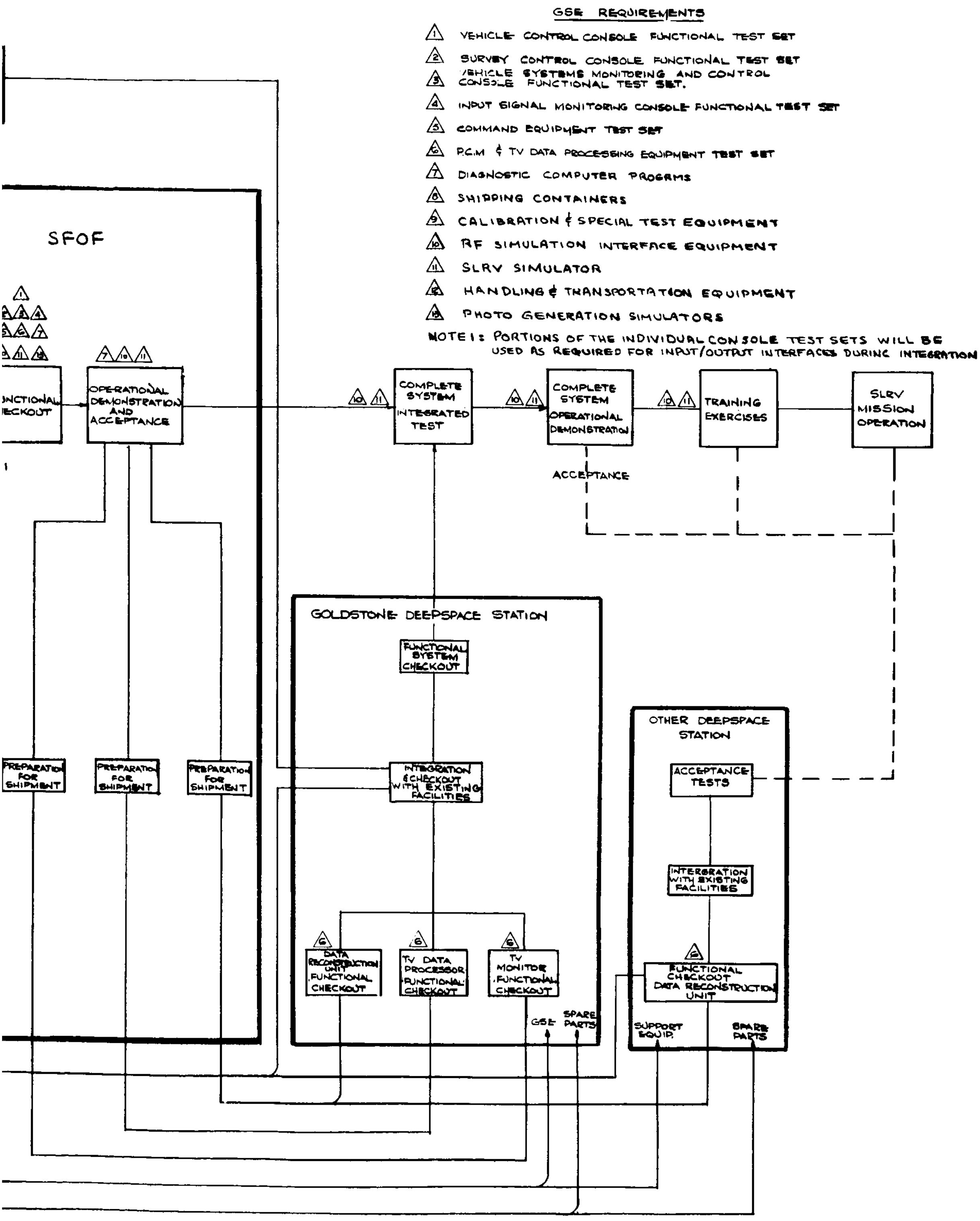

Figure 2.16-2 DSIF GOE Installation and Operational Profile

required to dissipate heat from the SLRV structure. The SLRV checkout facility should provide a suitable, non-explosive area for receiving, uncrating, and visual inspection, a clean room area and a bonded stores area for storage of space parts.

From the checkout area, the SLRV is moved into the explosive safe area and is prepared for final mission configuration. The RTG fuel capsule is received and functionally tested at this time and is installed in the SLRV, replacing the electric heater element. When the heating element is replaced, the RTG hermetic seal must be broken during the operation with subsequent evacuation of atmosphere, pressurization with an inert gas, and resealing. The unit is then subjected to a final gross functional check to assure proper operation of the RTG with the active fuel.

Explosive devices which have been subjected to individual no-fire tests are installed at this point and the SLRF is prepared and integrated into the flight-ready Surveyor Spacecraft.

Remaining procedures prior to launch follow standard Surveyor sequences including spacecraft weight, balance, cg check, fairing installation, confidence checks, on-pad mating, and system monitoring during countdown procedures. Cooling air for the SLRV must be supplied by Surveyor GSE prior to mating on the pad and by Centaur air conditioning equipment during pad checkout. SLRV functions which require monitoring after installation with Surveyor include general housekeeping data such as power supply voltages and temperatures. The SLOT and the STEA are supplemented as at Hughes Aircraft Corporation with specific SLRV control and monitoring equipment.

SLRV status will be monitored during launch pad procedures by a special SLRV blockhouse monitor console. This console is interconnected with the supplementary SLRV control and monitor equipment included in the SLOT. All on-pad checkout of the SLRV is provided through the SLOT/Surveyor RF link. No direct interfaces between GSE and the SLRV exist.

2.16.1.2 DSIF Ground Operating Equipment Installation and Operational Profile

Figure 2.16-2 illustrates the basic concept for the activities involved in installation and operation of GOE. Complete details of the integration sequences will be filled in during Phase II as firm hardware configurations become available.

The major elements of GOE are shown at the left of the diagram. After acceptance tests of the individual equipments at Bendix, the major elements will be shipped to the SFOF at JPL for integration with existing equipment facilities. In accordance with established policies for DSIF equipment, all operating equipments will be initially integrated and operationally verified at JPL before installation at associated DSS. Additional equipment not unique to the SLRV mission and referenced as mission independent equipment is provided under JPL cognizance and is integrated into the system concurrent with the SLRV GOE. This equipment is required to complete the system net but is not the direct responsibility of the SLRV contractor. However, SLRV mission requirements may have an effect on determining its necessity and performance characteristics.

Initial checkout and functional installation of the SLRV GOE at SFOF requires the support of considerable test equipment. Much of this equipment can be general purpose laboratory equipment but those special items necessary will be supplied as GSE by the SLRV contractor. As integration of the GOE elements with SFOF equipment progresses, less of the individual GSE is required since complementary GOE items provide their own interfaces. Ultimately, a final system demonstration at SFOF can be supported by a SLRV simulator and a set of interface equipment simulating the DSS functions.

After acceptance of functional elements at JPL, those required for installation at various remote DSS are packaged and shipped to the respective sites. An integration sequence at remote sites is required which uses special GSE for functional interfaces. After a final system functional checkout, the DSIF network is integrated and functional compatibility demonstrations are performed using the SLRV simulator. Following this, a considerable amount of operator training is required to verify the operational functions of the GOE system. These demonstrations and training exercises should be supported through remote operation of the SLRV simulator on a specially prepared test course.

Simulated mission functional tests will be performed to verify man/machine functional relationships of equipment and operator. Both operational and operator maintenance functions will be performed. The SLRV simulator will be used during the simulated mission tests. Among other things, the tests will verify or evaluate by demonstration of the following:

1. Ease of operator control

2. Positive control assurance

3. SLRV navigational problem solving

4. Operator proficiency

5. Maintainability of equipment

6. Mission problem solving.

Simulated mission training and confidence tests will ensure that the actual operator can perform his assigned function remembering what he has previously signaled, visualizing the exact mode of the SLRV with regard to position of tracks, speed, attitude, azimuth, and rate of turning. It also trains the group to work as a team to ensure that the operators coordinate SLRV requirements.

The equipment is now in a condition for operation readiness. It will be continuously cycled for assurance monitoring and calibration. During countdown the equipment will be turned on and checkout for active utilization will be performed.

2.16.2 GSE Design Concept

The GSE items required for support of the SLRV system elements identified in the operational profile are grouped for convenience in the hardware tree, Figure 2.16-3. Three categories of equipment are shown: (1) that equipment required to support the SLRV vehicle and its subsystems, (2) that required to support the modifications to be made to the Surveyor Spacecraft, and (3) that equipment required to support the installation and operation of the DSIP GOE. These categories are further expanded to show the individual items required for functional checkout, and maintenance, shipping, handling, and transportation of the end items, servicing, and alignment and calibration.

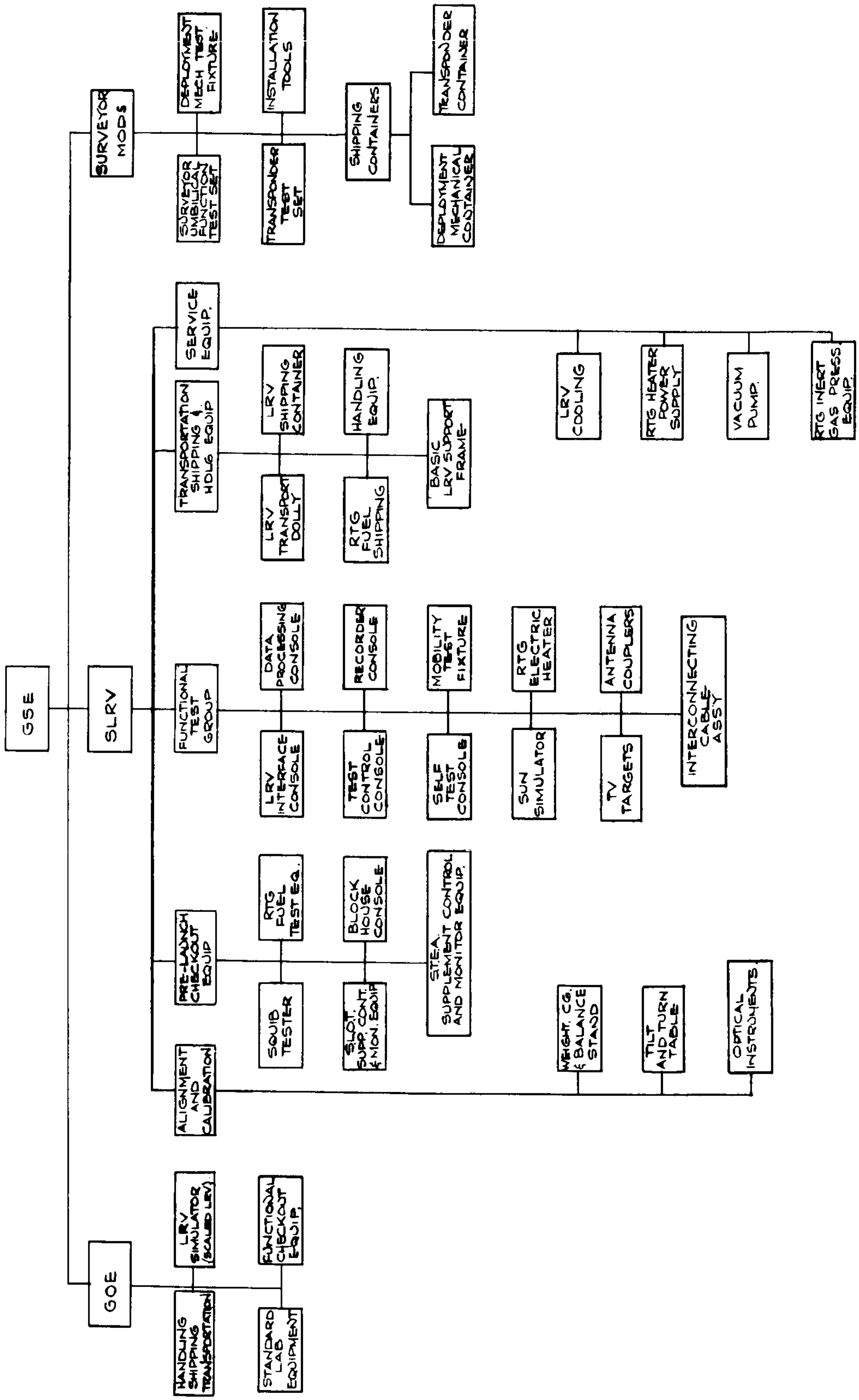

Figure 2.16-3 GSE-SLRV Hardware Tree

2.16.2.1 GSE for the SLRV

SLRV Functional Test Group

The SLRV functional test group includes the equipment required to test, calibrate, align, and fault isolate the electronic and electromechanical functions of the vehicle system. A functional block diagram of the integrated test set up is shown in Figure 2.16-4.

Electronic and electromechanical interfaces between the checkout equipment and the SLRV are shown at the right hand side of the diagram. These interfaces include the following functions:

1. Command
2. Telemetry
3. RF ranging
4. SLRV power
5. Mechanical interfaces with the traction drive mechanisms (TDM)
6. Stimulation of the sun sensors
7. TV targets
8. Surveyor/SLRV umbilical functions
9. Test connectors on various subsystem components
10. Mechanical interfaces with the penetrometer and inclinometer.

Commands are originated at the main test control console via the controls on the CDC command entry panel. The commands can be selected and programmed one at a time by the operator controls or sequentially through the paper tape reader available in the Surveryor CDC command subsystems. Encoding of commands into the correct format and modulation of an SCO is also accomplished by the CDC command subsystem. The

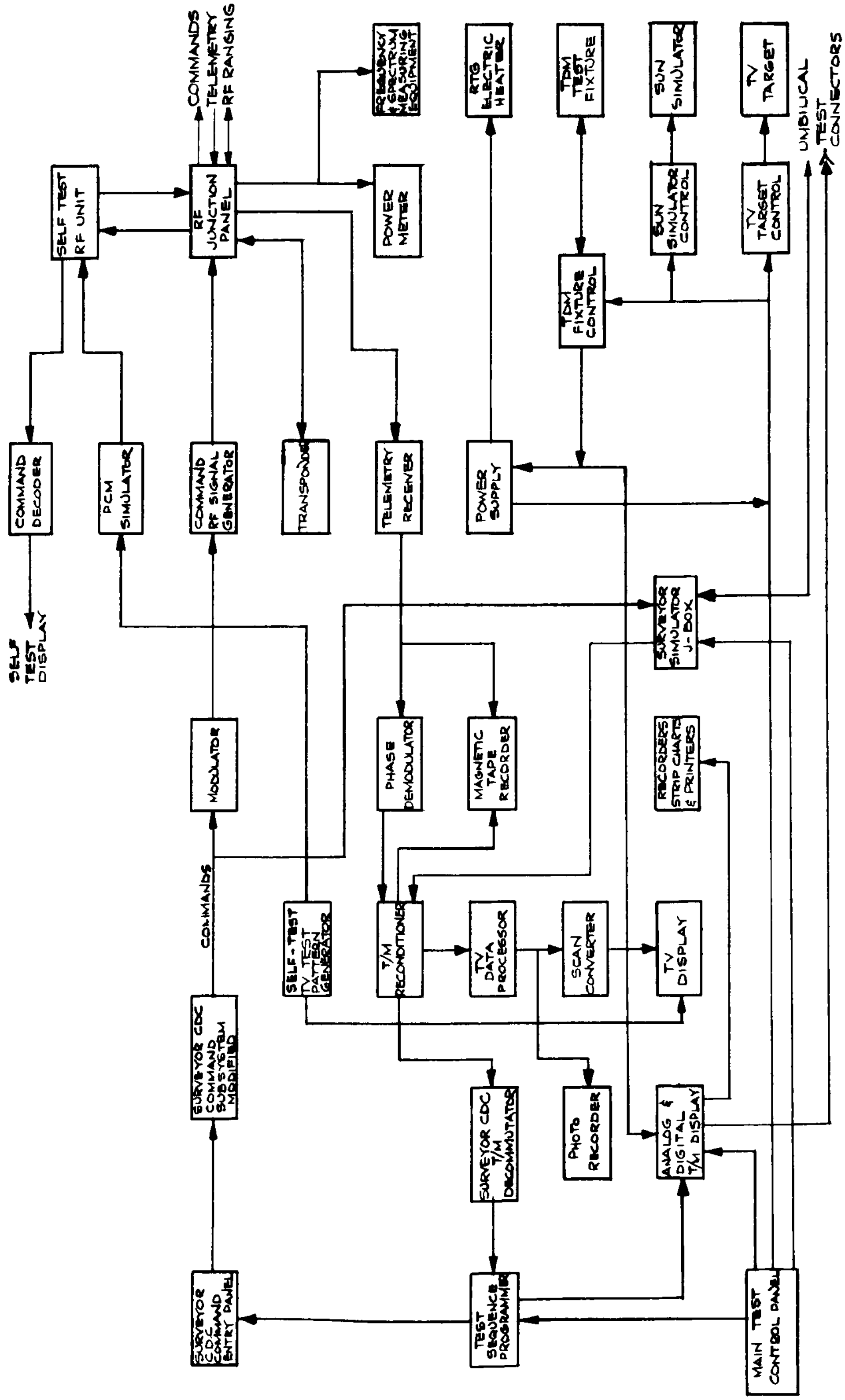

Figure 2.16-4 Functional Test Group Functional Block Diagram

modulated subcarrier is then applied to the RF modulator or can be directed to the Surveyor simulator junction box for signal processing. This latter function duplicates the Surveyor interface for checkout of the SLRV via umbilical connections. The command RF signal generator provides a modulated RF test signal which is adjustable in frequency, output level, and modulation level so that the various parameters of the SLRV command receiver and decoder subsystem can be completely tested. The output from the signal generator is applied to the RF junction panel which provides appropriate switching, sampling, and filtering. Connection to the SLRV can be provided either hard wire or through an air link via antenna coupling.

The telemetry from the SLRV is similarly coupled via hard wire or antenna link and is applied to the RF junction panel. The main RF power signal is directed to a load and an RF power meter. Appropriate levels are sampled and coupled to frequency and spectrum analysis equipment, and to a telemetry receiver. The IF output of the receiver is recorded on magnetic tape for a permanent test record prior to being demodulated. The telemetry processor reconditions the serial bit stream which is then applied to the Surveyor CDC decommutation equipment, and the TV data processor. The reconditioned data are also recorded on magnetic tape for subsequent playback if necessary. Decommutated data are applied to the test sequence programmer where they are sampled and conditioned for analog and digital displays. TV data are applied to the TV data processor and the scan converter for processing, storage, and display. Over-lays for the TV monitor are provided to allow quick-look analyses of picture quality and pointing accuracies. Permanent records are also produced in the photo recording equipment to enable complete analysis of TV resolution and to provide permanent test records. An array of chart recorders and digital printers provide permanent records and time histories of selected analog and digital telemetry data.

Telemetry inputs are also provided to the reconditioner via the Surveyor simulator J box and the umbilical connection. This function provides a check of the SLRV/Surveyor telemetry interface.

Additional signals may be programmed through the umbilical from the Surveyor simulator J box to simulate deployment commands. Outputs from the vehicle are interconnected to the display console via test connectors which replace explosive devices.

The SLRV DC power source is provided by using an electric heater element which replaces the active RTG fuel cell. A power supply in the test set provides the external power source. This approach is based upon installation of the RTG minus fuel (or a simulated RTG) during the factory build-up procedures of the SLRV and fueling it at the launch site. The overall support problem through the prelaunch sequences is complex in that it is necessary to keep the RTG from cooling down within a predetermined number of cycles. In addition, the installation and operation of the electric heater and the ultimate installation of the radioactive fuel during prelaunch operations require that the RTG thermocouples remain in an inert atmosphere. An alternate approach is to provide simulation of the RTG output characteristics in the test set power supply. This simulation would be difficult and might provide test results that would not correlate with actual RTG performance. A study of these support problems must be completed in Phase II prior to making a final decision.

The interface with the SLRV TDM is provided through an electromechanical test fixture. Control of the fixture mechanism is originated at the TDM fixture control panel and readouts are displayed at the control and monitor console. Simultaneous comparison of fixture reference parameters with vehicle telemetry responses are available at the display panel and subsequent analysis is provided through permanent records on chart recorders.

The mobility test fixture (Figure 2.16-5) consists of a basic frame and mounting plates for each function of test. The basic frame consists of two welded and aligned structures which clamp at each half of the SLRV vehicle. The mobility test fixture is capable of checkout and calibrating the following:

1. Traction drive mechanism
2. Odometer mechanism
3. Track pivoting capability
4. Structure turning capability
5. Command response.

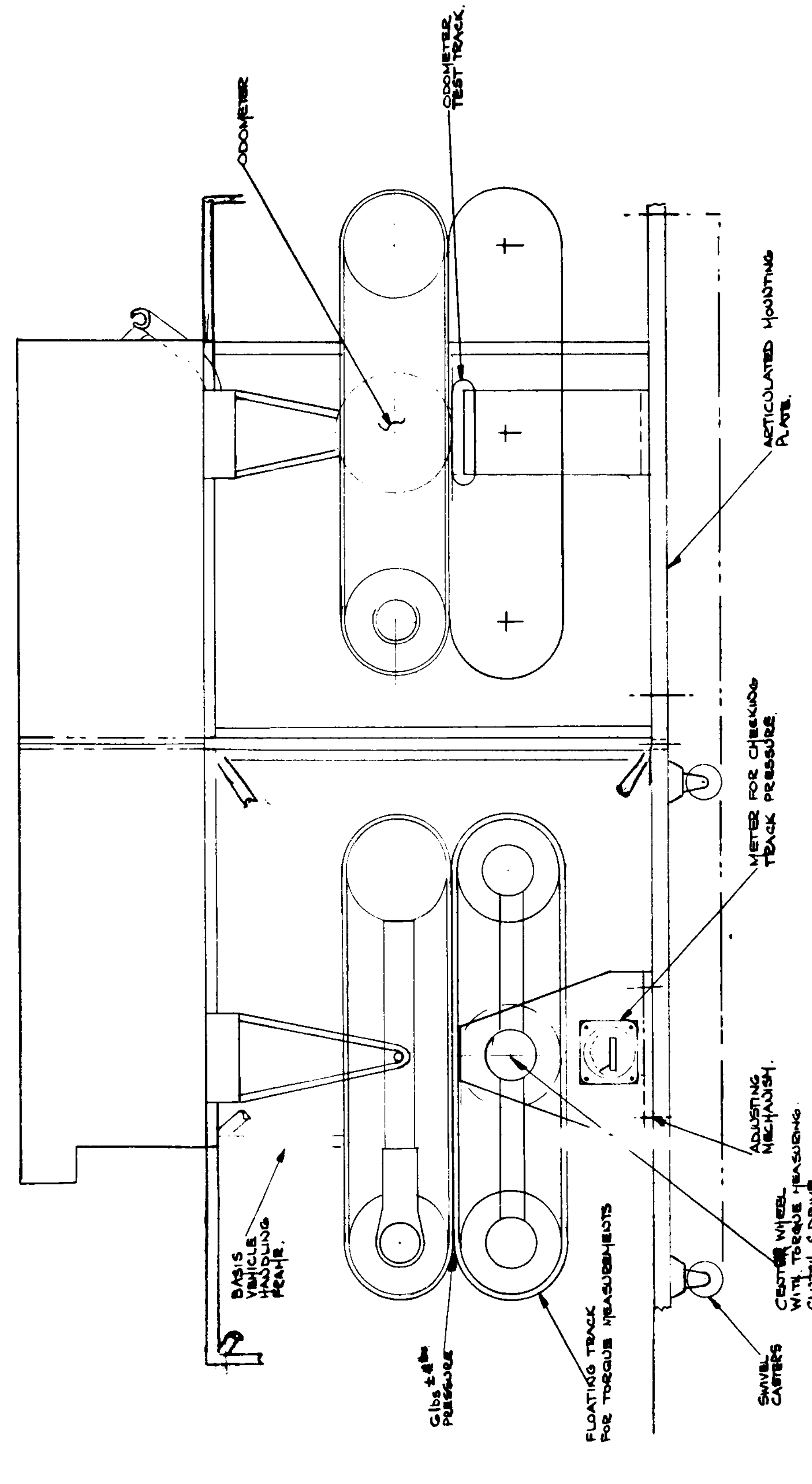

Figure 2.16-5 SLRV Mobility Test Fixture

The structure steering capability test fixture consists of two flat plates articulated to reassemble the movement of the vehicle.

The track driving mechanism fixture consist of a flat plate on which is mounted four track assemblies similar to the SLRV tracks. These tracks are located directly under each vehicle track and adjustable to maintain a pre-determined pressure on each track to simulate the gravity environment experienced on the lunar surface. Each test track is pivoted about the center drive wheel which is coupled to a magnetic brake. This center pivot of the test track maintains an equal load distribution on the vehicle track.

The calibration of the odometer reading is accomplished by a similar method, using a smaller test track.

The command response and pivoting checkouts are accomplished by the test console readout, and manual operation.

The penetrometer test is accomplished by probing a known soil sample. This test requires that the vehicle and handling frame be mounted on a stand above a pre-tested soil sample. The penetrometer is then operated by command from the test set, and recordings noted.

Stimulation of the TV sensor is provided through use of illuminated TV targets and test patterns. System performance is evaluated via comparison of photo recordings of the telemetered data with standard patterns and grey scales. Calibration and alignment of the TV pointing accuracies and fields of view are accomplished through a system of optical instrumentation.

The sun sensor is stimulated by a collimated light source located at a precise point external to the vehicle. The complete calibration, alignment, and acceptance test is accomplished by the optical instrumentation and rotating tilt table. Reference attitudes established by the optical system are compared to telemetered information.

Performance of the RF ranging equipment of the SLRV is evaluated by use of a special purpose transponder desinged to simulate a range of distances. The RF signals are fed to and from the SLRV through hardwire connections or through an antenna link. Switching in the RF panel allows measurement of RF power, frequency, and spectrum.

A complete self-verification capability is provided in the equipment group to enhance the confidence and reliability of the test results. The RF self-test unit in conjunction with command decoders and PCM simulators allows closure of the test equipment interface loops for a complete checkout of the GSE operation. In addition, the self-test equipment will be designed to provide fault isolation of the test system to replaceable drawer levels to increase maintainability and availability.

Preliminary configurations of the equipment required to implement the SLRV functional test group are illustrated in Figure 2.16-6. The electronic equipment has been functionally subdivided for housing in five console enclosures.

1. Test control and monitor console
2. SLRV interface console
3. Data processing console
4. Recorder console
5. Self test console.

Preliminary investigations show that many of the SLRV test functions are similar or duplicate those required for Surveyor test and checkout. Since the Surveyor equipment has been designed and fabricated, it requires only duplication. Other SLRV test functions duplicate those being considered for SLRV GOE to be installed at SFOF. Identical equipments will be used for both purposes where possible.

Present planning is to extend the design of the functional test group to the point of sophistication wherein test data can be recorded, compiled, and used in computer programs to implement failure trend analysis during the life of the SLRV. Test data accumulated throughout the factory and prelaunch sequences will be correlated with mission recorded data to complete the time history. It is possible, through these analyses, that predictions of pending failures can be made and degraded mission sequences initiated to prolong the equipment life. Studies during Phase II in conjunction with GSE, reliability, and maintainability engineers as well as with the SLRV and GOE designers will be undertaken to implement this program.

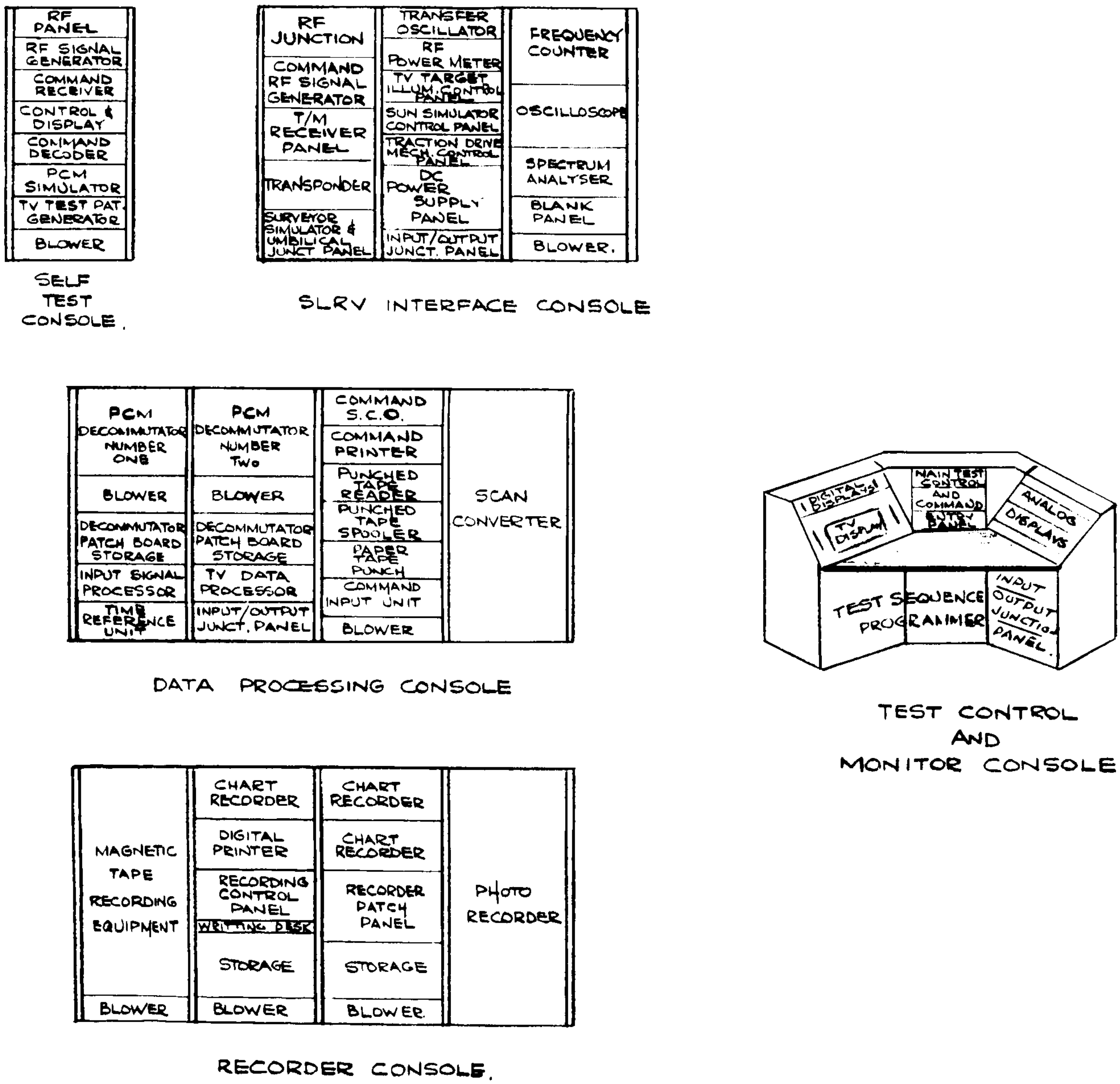

Figure 2.16-6 Functional Test Group Equipment Configuration

Pre-Launch Checkout Equipment Group

The prelaunch checkout equipment group provides items of functional test and monitor equipment necessary to support activities after integration of the SLRV with the Surveyor Spacecraft and up until the time of launch.

Presumably test interfaces will not be available to the SLRV itself after the vehicle has been integrated with Surveyor. All command and monitor functions required for SLRV checkout will consequently be processed through the Surveyor/SLRV umbilical connections, and the GSE interface will be strictly between Surveyor equipments. A minimum amount of control and monitor equipment will be required to supplement the Surveyor System test equipment assembly for integrated system tests.

Duplicate supplementary monitor and control equipment will be provided for integration with SLOT for launch pad checkout. This equipment will interface with the SLRV blockhouse monitor console which will be used during countdown procedures to monitor SLRV condition.

Support of integration sequences at AMR will require the use of a squib tester for checkout of pyrotechnics prior to installation in the SLRV deployment mechanism. It is expected that this tester is available and need not be duplicated.

Final disposition of the method for handling the RTG will determine the ultimate GSE requirements in this area. The suggested approach requires that a test set be available for checkout of the RTG fuel cell on receipt of the unit at the launch site and prior to installation. It is visualized that this unit probably will be a thermal measuring device: possibly a standard RTG thermocouple unit. The fuel cell would be placed in the test set and output voltage and current measurements would verify the thermal output of the radio active fuel.

SLRV Alignment and Calibration Equipment Group

This group of equipment includes a weight, balance, and cg test stand, a rotating tilt table, and a system of optical instruments. These equipments are required for supporting critical alignment adjustments and measurements and for performing calibration procedures which are necessary to supplement mission navigational techniques.

The navigational concept for the SLRV System required precise knowledge of the relative angles between the inclinometer, the sun sensor, and the TV camera. Some difficulty is foreseen in retaining the required accuracies between these sensors because of structural bending and misalignments as the vehicle traverses various terrains. The basic SLRV structural design will reduce these problems to a minimum. However, final alignments and calibration procedures must be performed under precisely controlled conditions to enable compilation of actual vehicle performance data. The transformation of data taken under earth gravity forces to predicted conditions of lunar gravity is of major consequence. The equipment concepts described below will be used to accommodate as much of the calibration as possible in an earth environment; however, a complete study of this problem will be undertaken during Phase II. It is possible that the only feasible solution may result in requiring a complete navigation calibration procedure performed during initial checkout of the SLRV after deployment on the lunar surface.

The calibration and alignment equipment (Figure 2.16-7) can align and calibrate the following SLRV sensors via optic measurements:

1. TV camera
2. Inclinometer
3. Solar aspect sensor
4. Antenna.

The fixture is comprised of the surface plate capable of optical alignment to represent the common data reference point of all the calibrating of the above equipment. Attached to this plate is a rotating and tilting table. The SLRV vehicle with attaching handling frame is mounted to a base plate on adjustable machined surface blocks; accurate alignment of the vehicle is performed optically using sensitive equipment collimeters and targets. This equipment is mounted on seismic isolated blocks at the three true position points and beamed in at the targets mounted on the equipment to assure the absolute straight reference line.

The base plate housing the vehicle is adjusted mechanically so that the vertical center line of the camera is mounted above the center

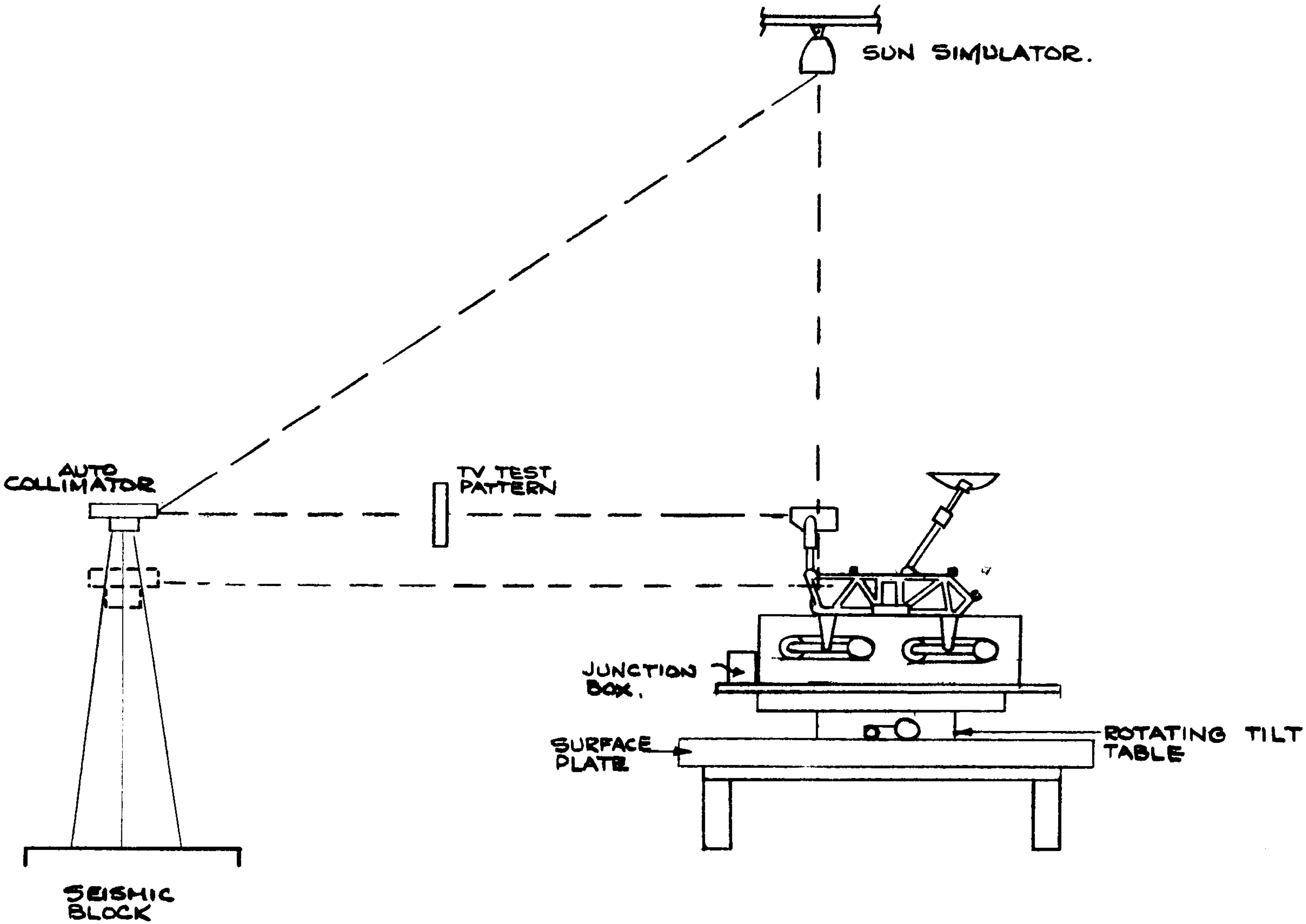

Figure 2.16-7 Optical Alignment Test Setup

line of a rotating table and again aligned optically, using a target or bench mark on the camera housing. True position and readout can be accurately ascertained by positioning the lens to 0^{o} on both elevation and azimuth planes. By rotating and tilting the table to any determined angle, comparison of readout by the test set equipment can readily assure the pointing accuracies of the camera. Lens focusing accuracy is checked out by placement of a TV test pattern at a fixed distance from the camera when the camera is locked in at 0^{o} position:

The inclinometer test procedure is performed similarly to the camera checkout with the basic set-up of alignment. Comparisons of known pitch and roll attitudes of the tilt table are made with the telemetered inclinometer readouts.

With the vehicle aligned to a true horizontal 0^{o} position and the vertical center line of the sun sensor mounted to the center line of the table, a pentaprism is located on the sun sensor. By sighting from the collimeter through the pentaprism a sun simulator can be located above the sun sensor and fixed in a permanent position. Then by rotating and tilting the table, the readout from the test set can determine the accuracy of azimuth and zenith planes of the sun sensors.

The antenna checkout procedure is similar to the other alignments, again mounting the vertical center of the antenna about the center line of the table, fixing true horizontal and azimuth at 0^{o} position, and moving the table in position required for test. Keeping the bore sight of the antenna aligned optically and commanding the antenna gimballing system as the reference table is turned and tilted provides a measure of antenna pointing capability.

SLRV Transportation, Shipping, and Handling Equipment

This group of equipment provides the capability for basic handling, shipping, and transportation of the SLRV and its subsystems. In accordance with the operational profile described previously, the SLRV will be shipped as a complete system except for installation of the RTG power supply fuel.

Special purpose shipping containers may be required which can supply power to the RTG electric heater element to keep it warm, and in addition, provide air conditioning to cool the complete SLRV.

Shipment of the RTG fuel imposes a similar problem of heat removal as well as that of shielding the radio activity. It is expected that shipping devices and handling methods for this will be completely handled by the AEC.

Special purpose handling equipment will be required to avoid damage to critical thermal surfaces and to flexible structural members during movement within a test area, assembly, or installation into shipping containers or on the Surveyor Bus. This handling equipment will use attachment points designed into the SLRV structure which will provide the required strength for support under the earth environment. These points will also be used as the reference for the SLRV/Surveyor interface so that master tooling can be made to control and check the mechanical fits. A basic SLRV support frame will be provided as handling equipment. This support frame attaches directly to the SLRV structure to provide rigidity. The frame is designed to pivot at the same centers of articulating SLRV bodies; however, a rigid cross member provides support to prevent sag at the joint. This basic frame remains with the SLRV from initial assembly to the time of installation on the Surveyor Spacecraft. All other handling, shipping, and transportation equipment as well as special test fixtures will attach to the basic support frame rather than to the SLRV structure.

Service Equipment Group

The Service Equipment Group includes equipment primarily required for support of the RTG power supply subsystem.

A standby power supply will be required to provide power to the electric heater at all times when the unit is not under test. In addition, a cooling system will be required continuously to remove heat from the SLRV. At present, a forced air system with a capacity of about 100 cfm is visualized as adequate, however, it may be necessary to use pre-cooled air.

Installation or replacement of the heater element in the RTG, whether it be the electric heater or the actual fuel cell, requires evacuation of the air and insertion of an inert atmosphere. A vacuum pump and the inert gas pressurization equipment are consequently provided as part of the service equipment package.

2.16.2.2 GSE for Surveyor Modification

Several items of support equipment are required to support modification and equipments added to Surveyor; these are discussed in the following paragraphs.

SLRV/Surveyor Umbilical Function Test Set

This test set will simulate basic functions of the SLRV to provide a checkout of the Surveyor umbilical connections. A PCM telemetry signal will be provided to stimulate the Surveyor processor. Monitoring of the results will be accomplished by the Surveyor System test equipment assembly. The command functions crossing the umbilical will be decoded in the test set and displayed for the correct indication. Other umbilical functions will similarly be checked out by the test set prior to mating of the two systems.

Deployment Mechanism Test Fixture

The deployment mechanism consists primarily of structural members which mate with the SLRV attachment points. The test fixture, consequently, will be made up of components made from master tooling. The fixture will be capable of checking the Surveyor attachment interface as installed on the spacecraft. In addition, the fixture will include SLRV envelope dimensions so that clearances and deployment procedure can be verified.

Transponder Test Set

The transponder test set includes a signal generator for checkout of the receiving components of the transponder and frequency and power measuring equipment for transmitter tests. Accurate measurements of the phase delays in the translator will be made in the test set to result in range calibration information. Hardwire connections to the input connections must be used to control the calibration procedure; however, facilities will be provided to allow a go/no-go checkout of the transponder system via an antenna link.

Final calibration of the RF ranging system would be accomplished during SLRV/Surveyor integration tests. A calibrated attenuator would be placed between the respective equipment diplexers and zero range measurements performed via SLRV telemetry signals.

Shipping Containers

Shipping containers will be provided for all Surveyor modification components. At present it appears that there are no special requirements other than protection from normal transportation handling shock and vibration.

The final requirement for surveyor modification support facilities has not been precisely determined at this time. It is possible, for example, that some (or all) of the components required for Surveyor modification will be specified by the SLRV contractor and fabricated by Hughes Aircraft Corporation. In this case, disposition of the GSE package would have to be resolved during the Phase II development program.

2.16.2.3 GSE for the Ground Operating Equipment

The GSE required for supporting the GOE to be installed at DSIF and SFOF facilities includes a functional test group, an SLRV simulator and transportation, handling, and shipping equipment.

The functional test group is used during initial installation and checkout of the GOE and as necessary for maintenance during operational use. It is presently contemplated that the GOE will include a complete self test capability; consequently, the major portion of the functional test group is expected to be standard laboratory instrumentation. Some special purpose simulators and interface junction boxes may be required for complete fault isolation and calibration. Diagnostic programs designed to checkout functionally the operation of the computational elements will also be provided. Complete analysis of the maintenance problems will be completed during Phase II to result in specific recommendations for GSE functions. For example, a complete array of individual drawer testers may be an ultimate requirement.

The SLRV simulator is visualized as a device to be used for final GOE acceptance demonstrations as well as for operator training exercises. This simulator would be an actual vehicle similar to the SLRV but scaled and modified to operate in the earth's gravity environment. The final necessity and desirability of this simulator should be considered during logistic studies in Phase II.

Shipping containers for the GOE components will be designed to meet standard ground and handling environmental conditions. No unique requirements for these items are contemplated.

2.16.3 Recommendations for GSE Implementation

The preceding discussion provides a preliminary basis for implementing the GSE system. Phase II expansion of this plan should be approached jointly by the SLRV contractor and JPL to provide a logical step-by-step analysis of the complete support problem. This approach will result in the most economical and realistic utilization of standard shelf items and inventoried special purpose items in conjunction with items requiring new development. As an example, several items required for Surveyor support are similar to those needed in the SLRV Program. These items could possibly be bailed to the SLRV contractor as GFE or duplication could be initiated with a minimum of redesign effort.

As in all programs, the definition and implementation of the GSE lags behind the operational equipment. Early recognition of the requirements and a joint effort between the customer and the contractor will help to prevent GSE scheduling problems.

SECTION 3

PERFORMANCE CHARACTERISTICS AND LIMITATIONS

Table 3.1-1 summarizes each key SLRV performance characteristic and limitation. Substantiation of this information is contained in Volume III, Book 2, for both the analytical and experimental items except for the ETM; this information is covered in Volume V.

TABLE 3.1-1

KEY SLRV PERFORMANCE CHARACTERISTICS

Function	Requirement	Capability
General		
SLRV System Weight	100 lb	100 lb
SLRV Configuration	HAC 239503	Feasible
SLRV Stowed cg	HAC 239503	Conforms
Mobility		
Speed, MPH	0.16	0.16
Steps, Climbing CM	30	42
Slopes, Climbing Degrees	15	22 Soft soil 41 Hard soil
Bearing Strength Gradient psi/ft	1.0	1.0
Crevice Crossing CM	30	29.2
Telecommunications		
Power (for 210' DSIF)	2 watts	2 watts
Bit Rate		
Normal Bits/sec	122,800	122,800 [1]
Emergency Bits/sec	960	960
Error Rate		
Normal	Max Acceptable 10^{3}	Under 10^{-3}
Emergency	Max Acceptable 10^{-3}	Under 10^{-3}
Antenna		
Omnidirectional Coverage Directional (Gain)	Hemispherical 17 db	243° 17 db
Scientific		
Protuberances and Depression detection CM	± 25	± 19
Slopes Degrees	8	8
Bearing Strength	(f vs z 8 psi to 50 cm)	(f vs z 9 psi to 50 cm)
Prime Power		
Day	Operate	OK
Night	Survival	OK
Navigation		
Azimuth Error	43 Arc-Minutes	35 Arc-Minutes [2]
Range Error (Interpoint)	1.3%	0.7% [3]
Range Error (Intrapoint)	0.7%	2% [4]
Deployment	15° slope with 10-cm obstacle	
Mission Life	105 Days	
Marking	Mark Site	

[1] SLRV communication link direct to DSIF

[2] Except for brief period around lunar midday

[3] Capability when within line of sight with Surveyor

[4] Can be improved when RF ranging is used.